ANNEX 4 ENVIRONMENTAL CHECKLIST

Environmental Checklist

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1. Permits and Consultation	(1) Environmental Assessment and Environmental Permits	(a)Have EIA reports been already prepared in official process?	N/A	(a)EIA or Initial Environmental Impact Assessment (IEIA) reports are not required for the Project. Apart from it, Initial Environmental Examination (IEE) had been conducted according to JICA guidelines.
		(b)Are the EIA reports written in the official or widely used language of the host country?	N/A	(b)EIA or Initial Environmental Impact Assessment (IEIA) reports are not required for the Project.
		(c)Have EIA reports been approved by authorities of the host country's government?	N/A	(c)EIA or Initial Environmental Impact Assessment (IEIA) reports are not required for the Project.
		(d)Have EIA reports been approved with any conditions? If conditions are imposed on the approval of EIA reports, are the conditions satisfied?	N/A	(d)EIA or Initial Environmental Impact Assessment (IEIA) reports are not required for the Project.
		(e)In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	Y	(e)In this project, among the EIA / IEIA / EPC (Environmental Protection Contract) stipulated in the environment-related law, only the EPC, which has the simplest procedure, is required. The EPC is being processed.
		(f)Do the EIA reports cover the items described in Appendix 2 of the JICA Guidelines?	N/A	(f)EIA or Initial Environmental Impact Assessment (IEIA) reports are not required for the Project.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(g)Do the environmental and social consideration confirmation cover the project's whole scope, cumulative impacts, derivative and secondary impacts, as well as impacts of indivisible projects?	Y	(g)The environmental and social consideration confirmation covered the project's whole scope, cumulative impacts, derivative and secondary impacts, as well as impacts of indivisible projects.
	(2) Explanation and Consultation with Local Stakeholders	(a)Are local stakeholders properly analyzed and identified?	Y	(a)Notification was made through each administrative district at least one week in advance, in writing, on notice boards and on social networking sites, and the target group included relevant ministries, administrative bodies, residents, NGOs, mass media, the poor and people with disabilities.
		(b)Does the project provide appropriate explanations to local stakeholders about the content and impact of the project, and gain their understanding, through the process of ensuring meaningful consultation including information disclosure?	Y	(b)Consultation meeting with local authorities and households were held in 8 Khans in Phnom Penh which cover the whole Project area: Khan Chbar Ampov (25 Sep 2023), Khan Dongkor (27 Sep 2023), Khan Por Senchey (28 Sep 2023), Khan Meanchey (29 Sep 2023), Takmao (29 Sep 2023), Sangkat Nirodh (11-Dec 2024), Sangkat Pong Tek (27-Dec 2024), Sangkat Choeung EK (27-Dec 2024), Khan Cbar Ampov (25-April 2025). In the meetings, contents of the project and the potential impacts been adequately explained and understanding was obtained from the local stakeholders.
		(c)For local stakeholder consultations, are records of consultations prepared, including the gender and other attributes of the participants?	Y	(c)Records of consultations prepared. Please refer to the main report.
		(d)Have the comment from the stakeholders (such as local residents) been reflected to the project design, etc.?	Y	(d)The Project is an expansion, not a new construction project. Thus, opinions concerning serious environmental impacts were not stated. On the other hand, some concerns such as: no clean water pipelines network, water pressure is slow, damaged road, traffic, noise, air quality (dust), suggestions for routes. In the meetings, the project plan

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
				to install and process the water treatment plant and need to speed up the clean water pipeline construction plan into the area where there is a shortage of clean water pipeline.
	(3) Examination of Alternatives	(a)Have alternative plans of the project been examined with social and environmental considerations?	Y	(a)The alternative studies (without project ⇔ with project) have been examined. In order to meet the water demand, "with project" option was selected.
	(3) Examination of Alternatives	(a)Is the project/plan's scope of multiple alternatives adequately considered?	Y	(a)Alternatives were considered. Please refer to the main report.
		(b)Are alternatives that are feasible in terms of technical, financial, and environmental and social aspects considered from the view point of environmental and social items and, if necessary, reducing total greenhouse gas emissions?	Y	(b)Alternatives were considered. Please refer to the main report.
		(c)Are comparisons made with the "without project" scenario?	Y	(c)The alternative studies (without project ⇔ with project) have been examined. In order to meet the water demand, "with project" option was selected.
2. Pollution	(1) Air Quality	(a) Is there a possibility that chlorine from chlorine storage facilities and chlorine injection facilities will cause air pollution? Are any mitigating measures taken?	Y	(a) For the safety of workers, the design ensures that the amount of chlorine exposure to the air is kept minimum. In other words, it has no external effects.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(b) Does chlorine from chlorine storage facilities and chlorine injection facilities cause air pollution?	N	(b) For the safety of workers, the design ensures that the amount of chlorine exposure to the air is kept minimum. In other words, it has no external effects.
		(c) Do chlorine concentrations within the working environments comply with the occupational health and safety standards of the host country, etc. ?	Y	(c) For the safety of workers, the design ensures that the amount of chlorine exposure to the air is kept minimum. Chlorine levels are monitored and the working environment is maintained to meet safety standards.
		(c)Do air pollutants, such as sulfur oxides (SOx), nitrogen oxides (NOx), and soot and dust comply with the emission standards of the host country, etc. ?	Y	(c)No air pollutants are expected to be produced. Furthermore, CO, NO_2, SO_2, TSP, PM10, PM2.5, O_3 stipulated in "Declaration No. 120 on Air Pollution Control and Noise Disturbance", will be monitored.
		(d)Do air pollutants emitted from the project cause areas that do not comply with the ambient air quality standards of the host country, etc. ?	N	(d)No air pollutants are expected to be produced.
		(e)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	Y	(e)Due to the operation of construction equipment and transportation vehicles, the generation of exhaust gas and dust will affect the atmosphere around the area. Therefore, mitigation measures such as the followings will be taken. 1) Cover stored materials with plastic or other materials. 2) Cover trucks and spray exposed areas with water. 3) Wash vehicles before leaving the site. 4) Minimize traffic over freshly exposed areas. 5) If necessary, install barriers to limit wind dispersion.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(2) Water Quality	(a)Do pollutants, such as SS, BOD, COD and pH, contained in effluents discharged by the facility operations comply with the effluent standards of the host country, etc. ?	Y	(a)While during operation phase, discharged water from the WTP will be produced. Currently, the impact on the surrounding environment is estimated to be little according to an Effluent Impact Study (refer to Annex 9). Thus, the waters should be discharged using the existing drainage system with the same process.
		(b)Does the quality of sanitary wastewater and stormwater comply with the effluent standards of the host country, etc. ?	Y	(b)Sewage from the WTP is connected to the sewage system and treated. Rainwater does not enter the drainage of the WTP and is not subject to effluent standards.
		(c)Do effluents from the project cause areas that do not comply with the ambient water quality standards of the host country, etc. ?	N	(c)Discharged water from the WTP will be produced. Currently, the impact on the surrounding environment is estimated to be little according to an Effluent Impact Study (refer to Annex 9). Thus, the waters should be discharged using the existing drainage system with the same process.
		(d)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	Y	(d)During construction phase, the amount of wastewater generated from the construction site is estimated to be very limited and treated.
	(3) Wastes	(a) Are wastes, such as sludge generated by the facility operations properly treated and disposed of in accordance with the regulations of the host country?	Y	(a) Sludge through water treatment process will be produced. Currently, the impact on the surrounding environment is estimated to be little according to an Effluent Impact Study (refer to Annex 9). Thus, the waters should be discharged using the existing drainage system with the same process.
		(b)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	Y	(b) During the construction phase: by arranging the appropriate storage site to avoid infiltration or seepage into the soil.
	(4) Soil	(a)Has the soil at the project site been contaminated in the past?	N	(a)No records of contamination in the past found.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	Contamination	(b)Are adequate measures taken to prevent contamination of soil?	Y	(b)Sludge from water treatment process in WTP will be adopted for the sludge treatment process. Leakage may occur in the future from the pipeline, but soil pollution is not expected to occur.
		(c)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?		(c)Fuel, motor oil or toilet waste water may be generated. Mitigation measures are; 1) Supervise the storage of liquid waste, especially liquid waste from the septic tank, fuel, concrete mixing and cement, by arranging a suitable storage location to prevent infiltration or seepage into the soil. 2) Construct a latrine with a septic tank for use by staff and workers in the workers' camp. 3) Sort solid waste into categories to facilitate management and cooperate with waste collection companies to transport it to the landfill. 4) Used motor oil waste is collected in storage containers for sale. 5) Build immediately after clearing and speed up construction to reduce impact on soil quality.
	(5) Noise and Vibration	(a) Do noise and vibrations from pumping facility comply with the standards of the host country, etc. ?	Y	(a) During the operational phase, noise and vibration will be minimized by covered pump house and tested by applying the standard.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(b)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	Y	(b) The construction works by all types of machines can cause producing noise and vibration. The current noise and vibration levels at the WTP site in the daytime and nighttime are lower than the standard of MoE. The impact will be considered and can be minimized by mitigation measures such as preparing a proper construction schedule / methods, setting speed limits for vehicles, using low noise level equipment, prohibition for trumpeting in unnecessary situation, carrying out monitoring, etc. Noise and vibration caused by pipeline construction is unavoidable, but will be minimised by complying with the schedule. Also, noise and vibration will be tested by applying the standard.
	(6) Subsidence	(a)In the case of extraction of a large volume of groundwater, is there a possibility that the extraction of groundwater will cause subsidence?	N	(a),(b) During construction and operation, no groundwater will be abstracted and no construction will affect the subsurface. Therefore, no subsidence effects are expected.
		(b)Will subsidence occur when large amounts of groundwater are pumped?		
		(c)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(c)No works that could cause land subsidence are in the plans.
3. Natural Environm	(1) Protected Areas	(a)Is the project site located in protected areas designated by the country's laws or international treaties/ conventions?	N	(a),(b),(c) The project sites are not located in protected areas. Also, there are no ecologically-sensitive areas in the immediate vicinity of the Project site (the nearest KBI (Key Biodiversity Area) and IBA (Important Bird and Biodiversity Area) are both more than 10km

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(b)Does the project affect the protected areas?		away from the Project area).
		(c)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?		
	(2) Biodiversity	(a) Does the project site encompass primary forests, natural forests in tropical areas, habitats with important ecological value (coral reefs, mangrove wetlands, tidal flats, etc.)?	N	(a) The project area is entirely a development area and does not include primary forests, tropical rainforests, ecologically valuable habitat forests, etc.
		(b) Does the project site encompass primary forests, natural forests in tropical areas, habitats with important ecological value (coral reefs, mangrove wetlands, tidal flats, etc.)?	Y	(b) IUCN Red List VU (Vulnerable) and NT (Near Threatened) species may be present in the release area, but are generally captured and not protected. In addition, the discharged water meets environmental standards.
		(c)Are there any concerns about the significant impact on biodiversity by the project, with significant conversion or significant degradation of critical habitats or critical forests? If yes, are appropriate measures taken to address the impact on biodiversity?	N	(c)No significant impact on biodiversity by the project is anticipated.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(d)Does the amount of water (e.g. surface water, groundwater) used by the project have a negative impact on the surrounding water bodies such as rivers? (Mitigation measures to reduce impacts on aquatic organisms should also be described in the "Confirmation of Environmental Considerations" column.)	N	(d) The expansion of the capacity is 200,000 m3/day and this accounts for only 0.14% of the average minimum flow of the Mekong River.
		(e) If there are any other concerns about significant impacts on biodiversity, are measures taken to reduce the impacts on biodiversity?	N	(c) No significant ecological impacts are anticipated.
		(f) Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(f) All construction sites are within developed areas and no significant impact on biodiversity by the project is anticipated.
		(g) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by project will adversely affect aquatic environments, such as rivers? Are adequate measures taken to reduce the impacts on aquatic environments, such as aquatic organisms?	N	(g) The expansion of the capacity is 200,000 m3/day and this accounts for only 0.14% of the average minimum flow of the Mekong River.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(3) Hydrology	(a) Does the amount of water used (e.g., surface water, groundwater) by the project adversely affect surface water and groundwater flows?	N	(a) Only 0.14% of the average minimum flow of the Mekong River will be consumed. No groundwater will be used.
		(b)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(b) Extensive water use and drainage will not occur during construction.

4. Social Environment	(1) Resettlement	(a)Is land acquisition with involuntary resettlement caused by project implementation? If yes, please describe the scale of land acquisition and resettlement. (b)Are efforts made to minimize the impacts caused by the resettlement? Are there any other land acquisition or loss of livelihoods? (c)Is adequate explanation on compensation and livelihood restoration program given to affected people prior to resettlement? (d)Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards, developed based on socioeconomic studies on resettlement? (e)Are the compensations paid prior to the resettlement? (f)Are the compensation policies prepared in document? (g)Does the resettlement plan pay particular attention to vulnerable social groups, such as women, children, elderly peoples, people in poverty, persons with disabilities, refugees,	N	(a) No resettlement or land acquisition are planned. (b) (c) (d) (e) (f) (g) (h) (i) (j) (k) (No resettlement or land acquisition are planned. On the other hand, part of the pipeline route passes through private land. The policy is to organize RAP equivalent documents and stakeholder meetings on the points required for this, and individual negotiations and consent attachments with each landowner will be carried out at the DD stage.)

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		internally displaced persons, and minorities? (h)Are the compensation to be agreed are explained to the project affected persons in writing, and are agreements with the affected people obtained prior to resettlement? (i)Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (j)Are any plans developed to monitor the impacts of resettlement? (k)Is the grievance redress mechanism established?		
	(2) Living and Livelihood	(a) Does the project adversely affect the living conditions of the inhabitants? Are adequate measures considered to reduce the impacts, if necessary?	N	(a) Although the construction works will cause temporary inconvenience, the water supply will improve the living standards of the citizens.
		(b) Does the amount of water (e.g. surface water, groundwater) used by the project cause adverse impacts to the existing water uses?	N	(a) Only 0.14% of the average minimum flow of the Mekong River will be consumed. No groundwater will be used.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(c)Does the project have a negative impact on ecosystem services (provisioning services and regulating services) and affect health and safety of the community (especially indigenous peoples who depend on the services)?	N	(c)The project is aimed at improving public health through the provision of water supply.
		(d)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(d)The project is aimed at improving public health through the provision of water supply.
	(3) Vulnerable Social Groups	(a)Is appropriate consideration given to vulnerable social groups, such as women, children, elderly peoples, people in poverty, persons with disabilities, refugees, internally displaced persons, and minorities?	Y	(a)Public meetings ensure that everyone can participate. And there are no deviations in the target of water supply.
		(b)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(b)Temporary inconvenience during construction, but no deviation in the PAP.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(4) Heritage	(a)Does the project damage any archeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the laws of the host country? (b)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(a) ,(b)There is a 'Killing Field' in the project area, which the pipeline route was designed to avoid.
	(5) Landscape	(a)Does the project adversely affect landscapes that require special considerations? (b)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N	(a),(b)Facilities in the WTP premises will be out of the public view. Thus, deterioration of landscape is not expected.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	(6) Ethnic Minorities and Indigenous Peoples	(a)Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b)Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources to be respected? (c)Is an indigenous peoples plan prepared and published, if necessary? (d)Do the project make efforts to obtain the Free, Prior, and Informed Consent (FPIC) of the affected indigenous peoples? (e)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	N/A	(a),(b),(c),(d),(e) No indigenous and ethnic minorities in the project area. This should not be the case as the project does not differ in construction or operation.
	(7) Working Conditions	(a) Does the project comply with laws related to occupational health and safety of the host country?	N	(a) The project proponent will not violate any laws and regulations relating to the working conditions in the country. The project proponent will comply with them.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(b) Are tangible safety considerations in place for individuals involved in the project, such as installation of safety equipment which prevents industrial accidents, and management of hazardous materials, etc.?	Y	(b) Tangible safety considerations for individuals are involved in the project, such as the installation of Personal Protective Equipment (PPE).
		(c)Are intangible measures being planned and implemented for individuals involved in the project, such as development of health and safety plans, and conducting safety trainings (including traffic safety and public health) for workers etc.?	Y	(c) The PPWSA has always had construction sites and established safety management methods that are applicable in this case.
	(8) Health, Safety and Security of Local Communities	(a)Are there any negative impacts on health/hygiene of the local community, such as disease outbreaks (including HIV and other infectious diseases) due to the influx of workers, etc. associated with the project? Are there any mitigation measures in place for the impacts?	N	(a)The Health/Hygiene Plan will be prepared as a separate supporting document as part of the Construction Environmental Management Plan (CEMP, internal safeguard document) under the supervision of the contractor and PPWSA.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(b)Are there any negative impacts on the safety of the local community, such as deterioration of public safety, due to the influx of workers, etc. associated with the project? Are there any mitigation measures in place for the impacts?	N	(b)Although accident from the construction activities or poor working environment can occur, the impacts will be considered can be minimized by mitigation measures such as an appropriate construction plan, safety education, regular inspection, proper accommodation, first aid medical equipment, sanitation facilities, access to medical services, personal protection equipment (PPE), etc.
		(c)When security guards are hired for the project or other personnel are deployed to ensure and maintain the security of the project area as well as the persons related to the implementation of the project during the project preparation and implementation, are any appropriate measures taken for such personnel not to use any force to provide security except for preventive and defensive purposes?		(c)Appropriate measures (e.g., ensure that workers are informed of the scope of their duties and sign a written pledge) to be taken for security guards and other personnel not to use any force to provide security except for preventive and defensive purposes.
		(d)Does the construction have negative impacts? Are there any mitigation measures in place for the impacts?	Y	(d)The Health/Hygiene Plan and worker influx plan will be prepared as a separate supporting document as part of the Construction Environmental Management Plan (CEMP, internal safeguard document) under the supervision of the contractor and PPWSA, in order to prevent negative impacts due to the influx of worker.

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
5. Others	(1) Monitoring	(a)Does the project proponent develop and implement monitoring program for the environmental and social items that are considered to have potential impacts?	Y	(a) An environmental monitoring plan has been prepared.

		(b)What are the items, methods and frequencies of the monitoring program?	Y	(b)The items, methods and frequencies of the monitoring plan are shown below.

Item Impact	Monitoring Parameter	Monitoring Frequency
1. Construction Phase		
Pollution		
Air pollution	CO, NO_2, SO_2, TSP, PM10, PM2.5, O_3	Once before the construction / Once every 6 months during the construction period.
Water pollution	pH, TDS, TSS, DO, BOD_5, COD, Oil or Grease, Detergent, TN, TP, SO_4, Pb, As, Cd, Fe, Hg, Total Coliform	Once before the construction / Once every 6 months during the construction period.
Waste water quality after treating	pH, Temperature, TDS, TSS, DO, BOD_5, COD, Oil or Grease, Detergent, NO_3, SO_4, PO_4, TN, TP, As, Fe, Hg, Mn, Total Coliform	Once before the construction / Once every 6 months during the construction period.
Waste	Volume of wastes	Check Regularly
Soil pollution	-	Check Regularly
Noise and vibration	Equivalent continuous a sound level and Vibration level	1time before every 6 months during the construction
Natural Environment		
Bio and ecosystems	Sedimentation controls, water quality control measures, temporary barriers and fences, fish feeding areas protection.	Check Regularly
Geographical	Alteration of topography	Check Regularly

features		
Social Environment		
Accidents	Items on the checklist (see Monitoring Form)	Check Regularly
Local economies / Community health, safety, and security / Gender / Existing social infrastructure and services	Changes that the construction will have on the surrounding area / Opinions of residents in the vicinity, etc.	Check Regularly
2. Operation Phase		
Pollution		
Air pollution	CO, NO_2, SO_2, TSP, PM10, PM2.5, O_3	Every 6 months
Water pollution	pH, TDS, TSS, DO, BOD_5, COD, Oil or Grease, Detergent, TN, TP, SO_4, Pb, As, Cd, Fe, Hg, Total Coliform	Every 6 months
Waste water quality after treating	pH, Temperature, TDS, TSS, DO, BOD_5, COD, Oil or Grease, Detergent, NO_3, SO_4, PO_4, TN, TP, As, Fe, Hg, Mn, Total Coliform	Every 6 months
Waste	Volume of wastes	In each case of disposal
Soil pollution	Volume (m^3) of treated sludge	In each case of disposal
Noise and vibration	Equivalent continuous a sound level and Vibration level	Every 6 months
Natural Environment		

<table>
<tr><th>Category</th><th>Item</th><th>Main Check Items</th><th>Yes: Y
No: N</th><th>Confirmation of Environmental Considerations
(Reasons, Mitigation Measures)</th></tr>
<tr><td></td><td></td><td></td><td></td><td>
<table>
<tr><td>Bio and ecosystems</td><td>-Water level
-Quantity</td><td>Every 6 months</td></tr>
<tr><td colspan="3">Social Environment</td></tr>
<tr><td>Accidents</td><td>Items on the checklist (see Monitoring Form)</td><td>Each day during operation</td></tr>
<tr><td>Hydrology / Water usage</td><td>-Water level
-Quantity</td><td>Check Regularly</td></tr>
<tr><td>Gender</td><td>-Working condition
-Number of personnel</td><td>Check Regularly</td></tr>
<tr><td>Climate change</td><td>-Operational status of solar panels.</td><td>Check Regularly</td></tr>
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</td></tr>
<tr><td></td><td></td><td>(c)Does the project proponent establish an adequate monitoring framework (organization, personnel, equipment, and budget to sustain the monitoring framework)?</td><td>Y</td><td>(c) The monitoring framework (organisation, staff, equipment and adequate budget to maintain the monitoring framework) has been prepared.</td></tr>
<tr><td></td><td></td><td>(d)Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reporting the monitoring results from the project proponent to the regulatory authorities?</td><td>Y</td><td>(d)Monitoring form has been proposed.</td></tr>
<tr><td></td><td></td><td>(e) Is the grievance redress mechanism regarding environmental and social considerations established?</td><td>Y</td><td>(e)Grievance redress mechanism has been proposed.</td></tr>
</table>

Category	Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
6 Note	(1)Reference to Checklist of Other Sectors	(a)Where necessary, pertinent items described in the Dam and River Projects checklist should also be checked.	N/A	(a) There are no dams in the vicinity and no need for river improvement, etc.
	(2)Note on Using Environmental Checklist	(a)Where necessary, the impacts to transboundary or global issues should be confirmed (e.g. the project includes factors that may cause problems, such as transboundary waste treatment or global warming).	N/A	(a)The Project does not include factors in terms of transboundary or global issues.
		(b)For projects that are expected to generate more than a certain amount of greenhouse gas emissions, is the total amount of the greenhouse gas emissions estimated before the project implementation?	N/A	(b)The project does not fall under any of the climate change projects listed in the Climate-FIT: Mitigation tool (JICA Climate-FIT: Mitigation) (JICA 2023).

ANNEX 5 ENVIRONMENTAL MONITORING FORM

Environmental Monitoring Form

M-1: [Pre-Construction Phase]

M-1-1 Air Quality

Monitoring Frequency: Once / **Implementation Schedule:** Before construction phase

Time and Date of the measurement (Nirodh WTP):..

No	Parameter	Unit	Result	Cambodian Standard (MoE)
1	Carbon monoxide (CO)	mg /m^3		< 20 (8h ave.)
2	Nitrogen dioxide (NO_2)	mg /m^3		< 0.1 (24h ave.)
3	Sulphur dioxide (SO_2)	mg /m^3		< 0.3 (24h ave.)
4	Dust (TSP)	mg /m^3		< 0.33 (24h ave.)
5	Dust (PM10)	mg /m^3		< 0.05 (24h ave.)
6	Dust (PM2.5)	mg /m^3		< 0.025 (24h ave.)
7	Ozone (O_3)	mg /m^3		< 0.2 (1h ave.)

M-1-2 Water Quality (River)

Monitoring Frequency: Once / **Implementation Schedule:** Before construction phase

Time and Date of the measurement Basak River near Nirodh WTP: ....

Time and Date of the measurement Mekong River near Intake: ....

No.	Parameters	Unit	Standards (river) of MoE	Results	
				Basak River	Mekong River
1	pH	-	6.5-8.5		
2	Total dissolved solid (TDS)	mg/L	-		
3	Total suspended solid (TSS)	mg/L	<100		
4	Dissolved oxygen (DO)	mg/L	>4		
5	Biochemical oxygen demand (BOD_5)	mg/L	<6		
6	Chemical oxygen demand $(COD)_{Mn}$	mg/L	<8		
7	Oil or Grease	mg/L	-		
8	Detergent	mg/L	-		
9	Total Nitrogen (TN)	mg/L	<2		
10	Total Phosphorus (TP)	mg/L	<0.15		
11	Sulphate (SO_4)	mg/L	-		
12	Lead (Pb)	μg/L	<10		
13	Arsenic (As)	μg/L	<10		
14	Cadmium (Cd)	μg/L	<3		
15	Iron (Fe)	mg/L	-		
16	Mercury (Hg)	μg/L	<0.5		
17	Total Coliform	MPN/100 ml	<1,000		

M-1-3 Water Quality (Wastewater)

Monitoring Frequency: Once / **Implementation Schedule:** Before construction phase

Time and Date of the measurement Discharged water from Nirodh WTP: ....

No.	Parameters	Unit	Standard for water area and sewer of MoE	Results
1	pH	-	5.5-9	
2	Temperature	°C	<40	
3	Total dissolved solid (TDS)	mg/l	-	
4	Total suspended (TSS)	mg/l	<100	
5	Dissolved oxygen (DO)	mg/l	-	
6	Biochemical oxygen demand (BOD_5)	mg/l	<60	
7	Chemical oxygen demand (COD)Cr	mg/l	<120	
8	Oil or Grease	mg/l	<10	
9	Detergent	mg/l	<10	

No.	Parameters	Unit	Standard for water area and sewer of MoE	Results
10	Nitrate (NO_3)	mg/l	<20	
11	Sulphate (SO_4)	mg/l	-	
12	Phosphate (PO_4)	mg/l	<5	
13	Total Nitrogen (TN)	mg/l	<40	
14	Total Phosphorus (TP)	mg/l	<6	
15	Arsenic (As)	mg/l	<0.1	
16	Iron (Fe)	mg/l	<5	
17	Mercury (Hg)	mg/l	<0.01	
18	Manganese (Mn)	mg/l	<3	
19	Total Coliform	MPN/100ml	-	

M-1-4 Noise

Monitoring Frequency: Once / **Implementation Schedule:** Before construction phase

Time and Date of the measurement (Nirodh WTP): ……………………………………………

Survey Period		Noise Level dB(A)			
		Standard (Leq)	**LAeq**	**Lmax**	**Lmin**
Day	6:00 - 7:00	**75**			
	7:00 - 8:00				
	8:00 - 9:00				
	9:00 - 10:00				
	10:00 - 11:00				
	11:00 - 12:00				
	12:00 - 13:00				
	13:00 - 14:00				
	14:00 - 15:00				
	15:00 - 16:00				
	16:00 - 17:00				
	17:00 - 18:00				
Evening	18:00 - 19:00	**70**			
	19:00 - 20:00				
	20:00 - 21:00				
	21:00 - 22:00				
Night	22:00 - 23:00	**50**			
	23:00 - 00:00				
	00:00 - 1:00				
	1:00 - 2:00				
	2:00 - 3:00				
	3:00 - 4:00				
	4:00 - 5:00				
	5:00 - 6:00				
24 hours (Average)					
Remark: Permitted in the area of moderate industrial zone mixing within the residential area, determined by the Ministry of Environment in (1) annex 1 of the Sub-Decree on the Control of Air Pollution and Noise Disturbances (2000) and Prakas No. 120 of the ToR for Infrastructure Development Projects and Tourism, dated 11 April 2018.					

M-1-5 Vibration

Monitoring Frequency: Once / **Implementation Schedule:** Before construction phase

Time and Date of the measurement (Nirodh WTP): ……………………………………………

Survey Period		Vibration level (dB)			
		Standard (Leq)	**Leq**	**Lmax**	**Lmin**
Day	6:00 - 7:00	**65**			
	7:00 - 8:00				
	8:00 - 9:00				
	9:00 - 10:00				
	10:00 - 11:00				

Survey Period		Vibration level (dB)			
		Standard (Leq)	Leq	Lmax	Lmin
	11:00 - 12:00				
	12:00 - 13:00				
	13:00 - 14:00				
	14:00 - 15:00				
	15:00 - 16:00				
	16:00 - 17:00				
	17:00 - 18:00				
Night	18:00 - 19:00	60			
	19:00 - 20:00				
	20:00 - 21:00				
	21:00 - 22:00				
	22:00 - 23:00				
	23:00 - 00:00				
	00:00 - 1:00				
	1:00 - 2:00				
	2:00 - 3:00				
	3:00 - 4:00				
	4:00 - 5:00				
	5:00 - 6:00				
24 hours (Average)					
Remark: In accordance with the standard level of vibration level in Prakas No. 120 of the ToR for Infrastructure Development Projects and Tourism, dated 11 April 2018 Ministry of Environment.					

M-1-6 Complain resulting from the Project

Monitoring Frequency: As needed / **Implementation Schedule:** Pre-construction phase

Subject of Complain	Content of Complain	Action Taken and Result
Component Date/Period By Mr./Ms. Contact information		

M-1-7 Land-use agreement

Monitoring Frequency: As processed / **Implementation Schedule:** Pre-construction phase

No.	Land owner	Location	Inside / outside (of roads)	Agreement on easements	Need for land acquisition	Scope (land alignment)

M-1-8 Scope changes that are expected to have environmental and social impacts

Monitoring Frequency: As processed / **Implementation Schedule:** Pre-construction phase

Content of the Scope Change	Expected Impact	Mitigation Status

M-2: [Construction Phase]

M-2-1 Air Quality

Monitoring Frequency: Once/3 months / **Implementation Schedule:** During construction phase

Time and Date of the measurement (Nirodh WTP):………………………………………………

No	Parameter	Unit	Result	Cambodian Standard (MoE)
1	Carbon monoxide (CO)	mg /m^3		< 20 (8h ave.)
2	Nitrogen dioxide (NO_2)	mg /m^3		< 0.1 (24h ave.)
3	Sulphur dioxide (SO_2)	mg /m^3		< 0.3 (24h ave.)
4	Dust (TSP)	mg /m^3		< 0.33 (24h ave.)
5	Dust (PM10)	mg /m^3		< 0.05 (24h ave.)
6	Dust (PM2.5)	mg /m^3		< 0.025 (24h ave.)
7	Ozone (O_3)	mg /m^3		< 0.2 (1h ave.)

M-2-2 Water Quality (River)

Monitoring Frequency: Once/3 months / **Implementation Schedule:** During construction phase

Time and Date of the measurement Basak River near Nirodh WTP: …………………………………

Time and Date of the measurement Mekong River near Intake: ………………………………………

No.	Parameters	Unit	Standards (river) of MoE	Results	
				Basak River	Mekong River
1	pH	-	6.5-8.5		
2	Total dissolved solid (TDS)	mg/L	-		
3	Total suspended solid (TSS)	mg/L	<100		
4	Dissolved oxygen (DO)	mg/L	>4		
5	Biochemical oxygen demand (BOD_5)	mg/L	<6		
6	Chemical oxygen demand $(COD)_{Mn}$	mg/L	<8		
7	Oil or Grease	mg/L	-		
8	Detergent	mg/L	-		
9	Total Nitrogen (TN)	mg/L	<2		
10	Total Phosphorus (TP)	mg/L	<0.15		
11	Sulphate (SO_4)	mg/L	-		
12	Lead (Pb)	µg/L	<10		
13	Arsenic (As)	µg/L	<10		
14	Cadmium (Cd)	µg/L	<3		
15	Iron (Fe)	mg/L	-		
16	Mercury (Hg)	µg/L	<0.5		
17	Total Coliform	MPN/100 ml	<1,000		

M-2-3 Water Quality (Wastewater)

Monitoring Frequency: Once/3 months / **Implementation Schedule:** During construction phase

Time and Date of the measurement Discharged water from Nirodh WTP: ……………………………

No.	Parameters	Unit	Standard for water area and sewer of MoE	Results
1	pH	-	5.5-9	
2	Temperature	°C	<40	
3	Total dissolved solid (TDS)	mg/l	-	
4	Total suspended (TSS)	mg/l	<100	

No.	Parameters	Unit	Standard for water area and sewer of MoE	Results
5	Dissolved oxygen (DO)	mg/l	-	
6	Biochemical oxygen demand (BOD_5)	mg/l	<60	
7	Chemical oxygen demand (COD)Cr	mg/l	<120	
8	Oil or Grease	mg/l	<10	
9	Detergent	mg/l	<10	
10	Nitrate (NO_3)	mg/l	<20	
11	Sulphate (SO_4)	mg/l	-	
12	Phosphate (PO_4)	mg/l	<5	
13	Total Nitrogen (TN)	mg/l	<40	
14	Total Phosphorus (TP)	mg/l	<6	
15	Arsenic (As)	mg/l	<0.1	
16	Iron (Fe)	mg/l	<5	
17	Mercury (Hg)	mg/l	<0.01	
18	Manganese (Mn)	mg/l	<3	
19	Total Coliform	MPN/100ml	-	

M-2-4 Waste / Soil pollution

Monitoring Frequency: Each day **/ Implementation Schedule:** During construction activities
Time and Date of the measurement (Nirodh WTP) :……………………………………………
Time and Date of the measurement (Pipeline) :……………………………………………

Monitoring item	Measurement point	Estimated volume (m^3)	Monitoring result during report period	Countermeasure (for improvement)
(Domestic waste) Designate temporary locations for garbage collection service			Good / To be improved	
			Good / To be improved	
			Good / To be improved	
(Construction waste) Designate waste disposal point			Good / To be improved	

M-2-5 Noise

Monitoring Frequency: Once/3 months **/ Implementation Schedule:** During construction phase
Time and Date of the measurement (Nirodh WTP):……………………………………………

Survey Period		Noise Level dB(A)			
		Standard (Leq)	**LAeq**	**Lmax**	**Lmin**
Day	6:00 - 7:00	**75**			
	7:00 - 8:00				
	8:00 - 9:00				
	9:00 - 10:00				
	10:00 - 11:00				
	11:00 - 12:00				
	12:00 - 13:00				
	13:00 - 14:00				
	14:00 - 15:00				
	15:00 - 16:00				
	16:00 - 17:00				
	17:00 - 18:00				
Evening	18:00 - 19:00	**70**			
	19:00 - 20:00				
	20:00 - 21:00				
	21:00 - 22:00				
Night	22:00 - 23:00	**50**			
	23:00 - 00:00				
	00:00 - 1:00				
	1:00 - 2:00				
	2:00 - 3:00				
	3:00 - 4:00				
	4:00 - 5:00				
	5:00 - 6:00				
24 hours (Average)					

Survey Period	Noise Level dB(A)			
	Standard (Leq)	LAeq	Lmax	Lmin
Remark: Permitted in the area of moderate industrial zone mixing within the residential area, determined by the Ministry of Environment in (1) annex 1 of the Sub-Decree on the Control of Air Pollution and Noise Disturbances (2000) and Prakas No. 120 of the ToR for Infrastructure Development Projects and Tourism, dated 11 April 2018.				

M-2-6 Vibration

Monitoring Frequency: Once/3 months **/ Implementation Schedule:** During construction phase
Time and Date of the measurement (Nirodh WTP): ………………………………………………

Survey Period		Vibration level (dB)			
		Standard (Leq)	Leq	Lmax	Lmin
Day	6:00 - 7:00	**65**			
	7:00 - 8:00				
	8:00 - 9:00				
	9:00 - 10:00				
	10:00 - 11:00				
	11:00 - 12:00				
	12:00 - 13:00				
	13:00 - 14:00				
	14:00 - 15:00				
	15:00 - 16:00				
	16:00 - 17:00				
	17:00 - 18:00				
Night	18:00 - 19:00	**60**			
	19:00 - 20:00				
	20:00 - 21:00				
	21:00 - 22:00				
	22:00 - 23:00				
	23:00 - 00:00				
	00:00 - 1:00				
	1:00 - 2:00				
	2:00 - 3:00				
	3:00 - 4:00				
	4:00 - 5:00				
	5:00 - 6:00				
24 hours (Average)					
Remark: In accordance with the standard level of vibration level in Prakas No. 120 of the ToR for Infrastructure Development Projects and Tourism, dated 11 April 2018 Ministry of Environment.					

M-2-7 Traffic (Accidents / Local economies)

Monitoring Frequency: Each day / **Implementation Schedule:** During construction phase
Time and Date of the measurement (Nirodh WTP): ………………………………………………
Time and Date of the measurement (Pipeline): ………………………………………………

Monitoring Item	Descriptive details	Measures to be Taken
Traffic		Arranging specific person for control the flow of traffic, Completing the construction works at the sections with traffic flow. Time to measure traffic flow. Count the number of vehicles.

M-2-8 Bottom sediments

Monitoring Frequency: On every occurrence / **Implementation Schedule:** During construction activities
Time and Date of the measurement (Nirodh WTP): ………………………………………………
Time and Date of the measurement (Pipeline) :

Monitoring item	Measurement point	Monitoring result	Countermeasure (for improvement)
Adequacy of turbidity treatment tank capacity.		Good / To be improved	
Status of sedimentation treatment.		Good / To be improved	
Cleanliness of treated water		Good / To be improved	

M-2-9 Changes by the construction on the surrounding area (Living and livelihood / Health, Safety, and Security of Local Communities / Gender / Existing social infrastructure and services)

Monitoring Frequency: On every occurrence / **Implementation Schedule:** During construction activities
Time and Date of the measurement (Nirodh WTP): ………………………………………………
Time and Date of the measurement (Pipeline) :

Monitoring item	Measurement point	Monitoring result	Countermeasure (for improvement)
Execution of the Health/Hygiene Plan for protection of the local community		Good / To be improved	
Execution of the Worker Influx Plan for protection of the local community		Good / To be improved	
Ensuring that workers are informed of the scope of their duties and sign a written pledge.		Good / To be improved	
Ensuring that roadside plot users, such as street vendors, are informed in advance about the detailed plans for the construction.		Good / To be improved	
Opinions and requests on the title	(Content)		

M-2-10 Working conditions
Monitoring Frequency: Each day / **Implementation Schedule:** During construction phase
Site of the measurement: Nirodh WTP and Pipeline
Safety Check Sheet:

Site:	Operator:
Date:	Time:

No.	Item	Eval	No.	Item	Eval
1	**Site Security/Safety**		4-8	Airport case	
1-1	Perimeter fencing		4-9	Shoes	
1-2	Signage		4-8	Other	
1-3	Lighting		**5**	**Earthwork**	
1-4	Other		5-1	Arrangement/planning	
2	**Site cleaning/hygiene**		5-2	Shoring	
2-1	Project Site		5-3	Site security/signage	
2-2	Office		5-4	Other	
2-3	Road		**6**	**Scaffold**	
2-4	Latrines		6-1	Condition of scaffolds	
2-5	Other		6-2	Condition of foundation	
3	**Environment**		6-3	Condition of supports	
3-1	Erosion prevention		6-4	Site security/signage	
3-2	Dust prevention		6-5	Other	
3-3	Dust bins/waste collection		**7**	**Heavy equipment**	
3-4	Other		7-1	Equipment condition	
4	**Protective Equipment (PPE)**		7-2	Wire condition	
4-1	Helmet		7-3	Hoist work procedure condition	
4-2	Protective eyewear		7-4	Site security/signage	
4-3	Mask		7-5	Other	
4-4	Protective wear		**8**	**Other Items**	
4-5	Safety harness		8-1	Accommodation of worker/staff	
4-6	Protective footwear		8-2	Fire equipment	
4-7	Work gloves		8-3	Safe water supply	

EVAL:	Good	○	To be improved	△	NA	／

Notes:

M-2-11 Water level (Flow-rate)

Monitoring Frequency: Each day / **Implementation Schedule:** During construction phase

Monitoring item	Time and Date	Water level (m)	Report (In case of abnormality)
Water level of Mekong River near the new Intake			

M-2-12 Complain resulting from the Project

Monitoring Frequency: As needed **/ Implementation Schedule:** During construction phase

Subject of Complain	Content of Complain	Action Taken and Result
Component Date/Period By Mr./Ms. Contact information		

M-2-13 Land-use agreement (change from Pre-construction conditions)

Monitoring Frequency: As processed **/ Implementation Schedule:** During construction phase

No.	Land owner	Location	Inside / outside (of roads)	Agreement on easements	Need for land acquisition	Scope (land alignment)

M-2-14 Complain from Land-owners

Monitoring Frequency: As needed **/ Implementation Schedule:** During construction phase

Subject of Complain	Content of Complain	Action Taken and Result
Component Date/Period By Mr./Ms. Contact information		

M-2-15 Scope changes that are expected to have environmental and social impacts

Monitoring Frequency: As processed **/ Implementation Schedule:** During construction phase

Content of the Scope Change	Expected Impact	Mitigation Status

M-3: [Operation Phase]

M-3-1 Water Quality (River)

Monitoring Frequency: Once/6 months **/ Implementation Schedule:** During operation phase
Time and Date of the measurement Basak River near Nirodh WTP: ……………………………
Time and Date of the measurement Mekong River near Intake: …………………………………

No.	Parameters	Unit	Standards (river) of MoE	Results	
				Basak River	Mekong River
1	pH	-	6.5-8.5		
2	Total dissolved solid (TDS)	mg/L	-		
3	Total suspended solid (TSS)	mg/L	<100		
4	Dissolved oxygen (DO)	mg/L	>4		
5	Biochemical oxygen demand (BOD_5)	mg/L	<6		
6	Chemical oxygen demand $(COD)_{Mn}$	mg/L	<8		
7	Oil or Grease	mg/L	-		
8	Detergent	mg/L	-		
9	Total Nitrogen (TN)	mg/L	<2		
10	Total Phosphorus (TP)	mg/L	<0.15		
11	Sulphate (SO_4)	mg/L	-		
12	Lead (Pb)	µg/L	<10		
13	Arsenic (As)	µg/L	<10		
14	Cadmium (Cd)	µg/L	<3		
15	Iron (Fe)	mg/L	-		
16	Mercury (Hg)	µg/L	<0.5		
17	Total Coliform	MPN/100 ml	<1,000		

M-3-2 Water Quality (Discharged water)

Monitoring Frequency: Once/3 months **/ Implementation Schedule:** During operation phase
Time and Date of the measurement Discharged water from Nirodh WTP: ……………………

No.	Parameters	Unit	Standard for water area and sewer of MoE	Results
1	pH	-	5.5-9	
2	Temperature	°C	<40	
3	Total dissolved solid (TDS)	mg/l	-	
4	Total suspended (TSS)	mg/l	<100	
5	Dissolved oxygen (DO)	mg/l	-	
6	Biochemical oxygen demand (BOD_5)	mg/l	<60	
7	Chemical oxygen demand (COD)Cr	mg/l	<120	
8	Oil or Grease	mg/l	<10	
9	Detergent	mg/l	<10	
10	Nitrate (NO_3)	mg/l	<20	
11	Sulphate (SO_4)	mg/l	-	
12	Phosphate (PO_4)	mg/l	<5	
13	Total Nitrogen (TN)	mg/l	<40	
14	Total Phosphorus (TP)	mg/l	<6	
15	Arsenic (As)	mg/l	<0.1	
16	Iron (Fe)	mg/l	<5	
17	Mercury (Hg)	mg/l	<0.01	
18	Manganese (Mn)	mg/l	<3	
19	Total Coliform	MPN/100ml	-	

M-3-3 Waste / Soil pollution

Monitoring Frequency: On every occurrence **/ Implementation Schedule:** During operation phase
Time and Date of the measurement (Nirodh WTP) :____________________Time and Date of the measurement (Pipeline) :

Monitoring item	Measurement point	Estimated volume (m^3)	Monitoring result during report period	Countermeasure (for improvement)
(Domestic waste) Designate temporary locations for garbage collection service			Good / To be improved	
			Good / To be improved	
			Good / To be improved	
(Construction waste) Designate waste disposal point			Good / To be improved	
(Soil pollution) Oil leaks from heavy machinery and vehicles			Good / To be improved	

M-3-4 Noise

Monitoring Frequency: Once/6 months **/ Implementation Schedule:** During operation phase
Time and Date of the measurement (Nirodh WTP): ……………………………………………

Survey Period		Noise Level dB(A)			
		Standard (Leq)	LAeq	Lmax	Lmin
Day	6:00 - 7:00	75			
	7:00 - 8:00				
	8:00 - 9:00				
	9:00 - 10:00				
	10:00 - 11:00				
	11:00 - 12:00				
	12:00 - 13:00				
	13:00 - 14:00				
	14:00 - 15:00				
	15:00 - 16:00				
	16:00 - 17:00				
	17:00 - 18:00				
Evening	18:00 - 19:00	70			
	19:00 - 20:00				
	20:00 - 21:00				
	21:00 - 22:00				
Night	22:00 - 23:00	50			
	23:00 - 00:00				
	00:00 - 1:00				
	1:00 - 2:00				
	2:00 - 3:00				
	3:00 - 4:00				
	4:00 - 5:00				
	5:00 - 6:00				
24 hours (Average)					
Remark: Permitted in the area of moderate industrial zone mixing within the residential area, determined by the Ministry of Environment in (1) annex 1 of the Sub-Decree on the Control of Air Pollution and Noise Disturbances (2000) and Prakas No. 120 of the ToR for Infrastructure Development Projects and Tourism, dated 11 April 2018.					

M-3-5 Vibration

Monitoring Frequency: Once/6 months / Implementation Schedule: During operation phase
Time and Date of the measurement (Nirodh WTP): ……………………………………………

Survey Period		Vibration level (dB)			
		Standard (Leq)	Leq	Lmax	Lmin
Day	6:00 - 7:00	65			
	7:00 - 8:00				
	8:00 - 9:00				
	9:00 - 10:00				
	10:00 - 11:00				
	11:00 - 12:00				
	12:00 - 13:00				
	13:00 - 14:00				

	14:00 - 15:00				
	15:00 - 16:00				
	16:00 - 17:00				
	17:00 - 18:00				
Night	18:00 - 19:00	**60**			
	19:00 - 20:00				
	20:00 - 21:00				
	21:00 - 22:00				
	22:00 - 23:00				
	23:00 - 00:00				
	00:00 - 1:00				
	1:00 - 2:00				
	2:00 - 3:00				
	3:00 - 4:00				
	4:00 - 5:00				
	5:00 - 6:00				
24 hours (Average)					
Remark: In accordance with the standard level of vibration level in Prakas No. 120 of the ToR for Infrastructure Development Projects and Tourism, dated 11 April 2018 Ministry of Environment.					

M-3-6 Water level (Bio and ecosystems / Hydrology / Geographical features)

Monitoring Frequency: Each day / **Implementation Schedule:** During operation phase

Monitoring item	Time and Date	Water level (m)	Report (In case of abnormality)
Water level of Mekong River near the new Intake			

M-3-7 Working conditions

Monitoring Frequency: Each day / **Implementation Schedule:** During operation phase
Site of the measurement: Nirodh WTP

Safety Check Sheet:

Site:	Operator:
Date:	Time:

No.	Item	Eval	No.	Item	Eval
1	**Site cleaning/hygiene**		**3**	**Environment**	
1-1	Project Site (WTP)		3-1	Bins/waste collection	
1-2	Office		3-2	Other	
1-3	Other		3-3	Condition of supports	
2	**Protective Equipment (PPE)**		3-4	Other	
2-1	Helmet		**4**	**Other Items**	
2-2	Protective eyewear		4-1	Accommodation of worker/staff	
2-3	Mask		4-2	Fire equipment	
2-4	Protective wear		4-3	Water supply (drinking water and clean water)	
2-5	Safety harness		4-4	Medical supplies for first aid	
2-6	Protective footwear				
2-7	Work gloves				
2-8	Airport case				
2-9	Shoes				
2-10	Other				

EVAL:	Good	○	To be improved	△	NA	／

Notes:

M-3-8 Climate change

Monitoring Frequency: Each month / **Implementation Schedule:** During operation phase
Time and Date of the measurement：

Monitoring item	Measurement point	Monitoring result	Countermeasure (for improvement)
External view of the Solar Power Generation System (damage, etc.)		Good / To be improved	
Dust settling on solar power systems		Good / To be improved	
Amount of electricity generated		Good / To be improved	

M-3-9 Complain resulting from the Project

Monitoring Frequency: As needed / **Implementation Schedule:** During operation phase

Subject of Complain	Content of Complain	Action Taken and Result
Component Date/Period By Mr./Ms. Contact information		

M-3-10 Land-use agreement (change after construction)

Monitoring Frequency: As processed **/ Implementation Schedule:** During operation phase

No.	Land owner	Location	Inside / outside (of roads)	Agreement on easements	Need for land acquisition	Scope (land alignment)

M-3-11 Complain from Land-owners

Monitoring Frequency: As needed **/ Implementation Schedule:** During operation phase

Subject of Complain	Content of Complain	Action Taken and Result
Component Date/Period By Mr./Ms. Contact information		

M-3-12 Scope changes that are expected to have environmental and social impacts

Monitoring Frequency: As processed **/ Implementation Schedule:** During operation phase

Content of the Scope Change	Expected Impact	Mitigation Status

ANNEX 6 NIRODH EFFLUENT IMPACT STUDY

NIRODH EFFLUENT IMPACT STUDY

≪ The Outline of the Results ≫

MAY 2025

JAPAN INTERNATIONAL COOPERATION AGENCY

NIHON SUIDO CONSULTANTS CO., LTD.

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ABBREVIATIONS

Al	Aluminum
As	Arsenic
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
Fe	Iron
Hg	Mercury
Mn	Manganese
MOE	Ministry of Environment
MPN	Most Probable Number
NO3	Nitrate
PO4	Phosphate
SO4	Sulphate
T-Coli	Total Coliforms
TDS	Total Dissolved Solid
T-N/TN	Total Nitrogen
T-P/TP	Total Phosphorus
TSS	Total Suspended Solids
VSS	Volatile Suspended Solids
WTP	Water Treatment Plant

1. Purpose

As a result of the "Preparatory Survey on Nirodh Water Supply Expansion Project", it was confirmed that Total Suspended Solids (TSS) exceeded the Cambodian national effluent standard[1] of 100 mg/L at the discharge point from the existing Nirodh Water Treatment Plant (WTP). Therefore, studies were conducted to determine the environmental impact of the effluent from the WTP on the Bassac River to which the effluent is discharged.

2. Outline

Currently, the Nirodh WTP takes water from the Mekong River and discharges effluent into the Bassac River, a tributary of the Mekong River. In the Bassac and Mekong Rivers, turbidity and TSS are high, and there are seasons when the TSS is over the discharge standard of 100 mg/L. Therefore, the environmental impact of discharging untreated WTP effluent into rivers with water quality exceeding the discharge standard is considered to be insignificant.

TSS refers to small particles of 2mm or less in diameter that are not fully dissolved in water, and is an important indicator of water pollution. However, TSS itself is not necessarily toxic; if the constituents of TSS contain many toxic substances or substances with high oxygen demand, there is concern about the impact on the environment and ecosystems.

This study investigated the impact on the Bassac River of discharged water quality items including TSS and iron (Fe), which exceed the standard values in the discharge standard, if discharged without treatment.

3. Survey Items

1) Survey points

The survey point consists of a total of 16 points, including 7 basic points and 9 auxiliary points.

≪Basic points≫

- Bassac River discharging point and nearby
  (50 m upstream from the discharge point and 0 m, 10 m, and 50 m downstream from the discharge point)
- Mekong River (water intake point)
- Raw water from WTP(collected in Nirodh WTP)
- Effluent from the WTP (collected at the Nirodh WTP)

≪Auxiliary points≫

- Lower Bassac River Basin (3×3=9 points at 0m, 50m, and 100m from the left bank at 100m, 150m, and 200m downstream from the discharge outlet)

2) Number of inspections

The number of inspections is to be a total of 4 times, consisting of 2 times during the rainy season and 2

[1] MOE Standards of wastewater discharging (public water area types 2) in Annex 2 of Sub-Decree No. 103, dated June 29, 2021

times during the dry season.

3) Water Quality Parameters

The water quality parameters consist of 23 items at the basic points and 3 items at the auxiliary points.

≪Basic points≫

- Cambodia's discharge standard items (19 items in total as shown in **Table 3-1**)

Table 3-1 Cambodia's discharge standard items

No.	Parameters	Unit	Standards for Effluent
1	pH	-	5.5-9
2	Temperature	°C	<40
3	Total dissolved solids (TDS)	mg/L	-
4	Total suspended solids (TSS)	mg/L	<100
5	Dissolved oxygen (DO)	mg/L	-
6	Biochemical oxygen demand (BOD_5)	mg/L	<60
7	Chemical oxygen demand (COD_{Cr})	mg/L	<120
8	Oil or Grease	mg/L	<10
9	Detergent	mg/L	<10
10	Nitrate (NO_3)	mg/L	<10
11	Sulphate (SO_4)	mg/L	-
12	Phosphate (PO_4)	mg/L	<5
13	Total nitrogen (TN)	mg/L	<40
14	Total phosphorus (TP)	mg/L	<6
15	Arsenic (As)	mg/L	<0.1
16	Iron (Fe)	mg/L	<5
17	Mercury (Hg)	mg/L	<0.01
18	Manganese (Mn)	mg/L	<3
19	Total coliform	MPN/100 ml	-

* MPN (Most Probable Number) is a method for estimating the number of bacteria in water using culture experiments and statistical analysis, rather than directly counting them.
Source: MOE Standards of wastewater discharging (public water area types 2)

- Total Aluminum
- Chlorine Residue
- VSS (Volatile Suspended Solids)
- Turbidity

≪Auxiliary points≫

- TSS
- Fe
- Turbidity

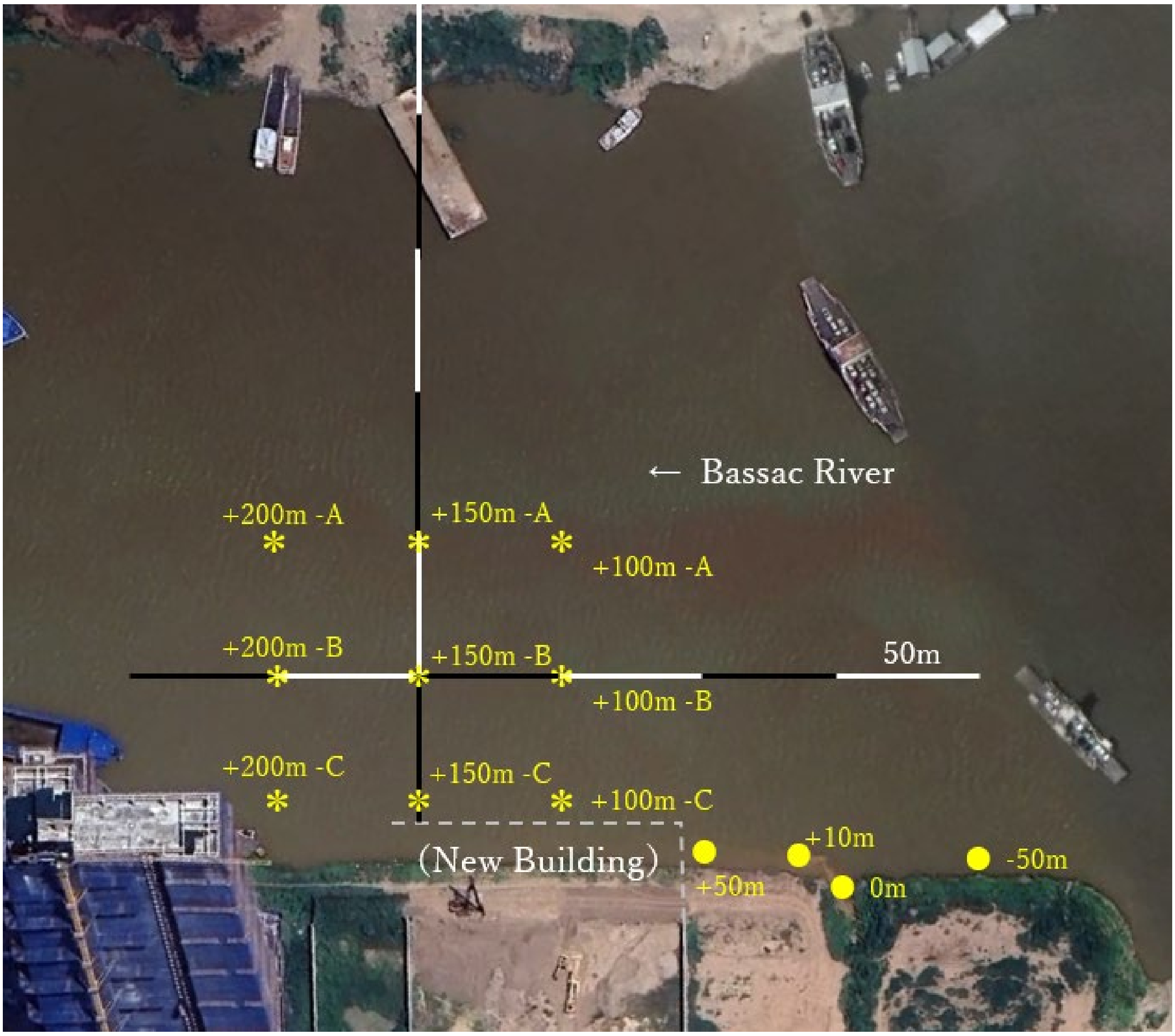
4) The Locations

The sampling locations are shown in **Figure 3-1** and **Figure 3-2**.

Source: JST

＜Basic Points＞ Raw water intake point, Raw water, Direct effluent

Figure 3-1 Locations of Sampling Points(1)



Source: JST

Bassac River discharging point and nearby ＜Basic Points ● / Auxiliary points ＊＞

Figure 3-2 Locations of Sampling Points(2)

5) The Sampling Method

5)-1 Effluent

Sample collection of effluent in the Nirod WTP was performed at the collection point using a basin where miscellaneous effluent/rainwater is mixed because the desludge/backwash water from the WTP is intermittent and cannot be collected stably.

Despite the above, efforts were made to identify changes in concentration as much as possible, and water samples were taken during the first and second wet season samplings, when high concentration of effluent (during sludge drainage) and low concentration of effluent (during backwash) were dominant, respectively. Furthermore, during the first and second dry season samplings, in collaboration with the water treatment operators, it was possible to collect representative samples during sludge drainage and backwash.

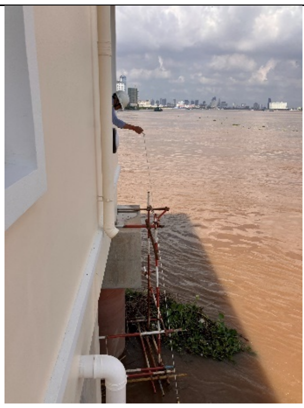
5)-2 Bassac River

Sampling was only conducted when the Bassac River was flowing in a forward (southward) direction.

Sample waters on the Bassac River were conducted at a depth of 50 cm at a distance of 1.5 m from the river bank to avoid the influence of the river bank.

Sample waters in the lower reaches of the Bassac River were conducted from a boat, starting from the downstream side. Water sampling shall be conducted at a depth of 50 cm.

The 0 m point was an exception. During the rainy season, water was collected at a depth of 50 cm when the discharge outlet was buried due to high water levels, and during the dry season, water was collected directly from the discharge outlet (see **Figure 3-3** for sampling conditions).

	
New Intake	**Raw Water**
	
Effluent	**Bassac River**

	
0m on Bassac River – Rainy Season (sampling at the closest point due to submerged water discharge outlet)	**0m on Bassac River – Dry Season (Direct collection from the discharge outlet)**

Source: JST

Figure 3-3 The Sampling Methods

4. Outline of the Results

The first survey during the rainy season was conducted on October 17, 2024, and the second survey during the rainy season was conducted on October 31, 2024. The first survey during the dry season was conducted on November 22, 2024, and the second survey of the dry season was conducted on December 6, 2024. The river conditions for all four surveys are shown in **Table 4-1**.

Table 4-1 River Conditions of the Survey

Date	Interval	Survey	Water level (comparative)	Velocity
2024/10/17	-	Rain-I	0m	Approx. 1m/s
2024/10/31	2 weeks later	Rain-II	Approx. -1m	-
2024/11/22	5 weeks later	Dry-I	Approx. -3m	Approx. 0.5m/s
2024/12/06	7 weeks later	Dry-II	Approx. -4m	-

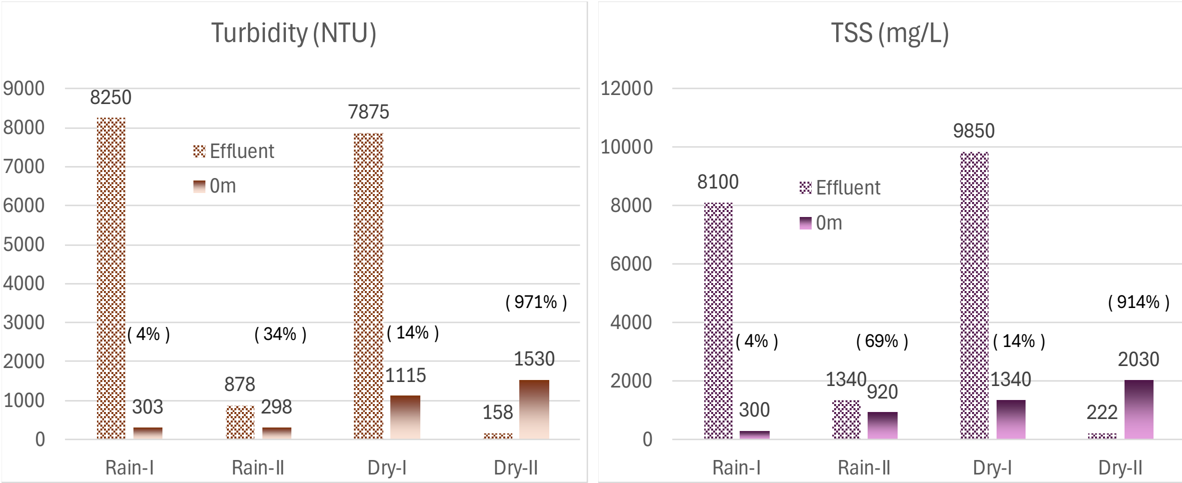
Source: JST

The followings are the results of water quality measurements and discussion based on them.

1) "Effluent" and its discharge

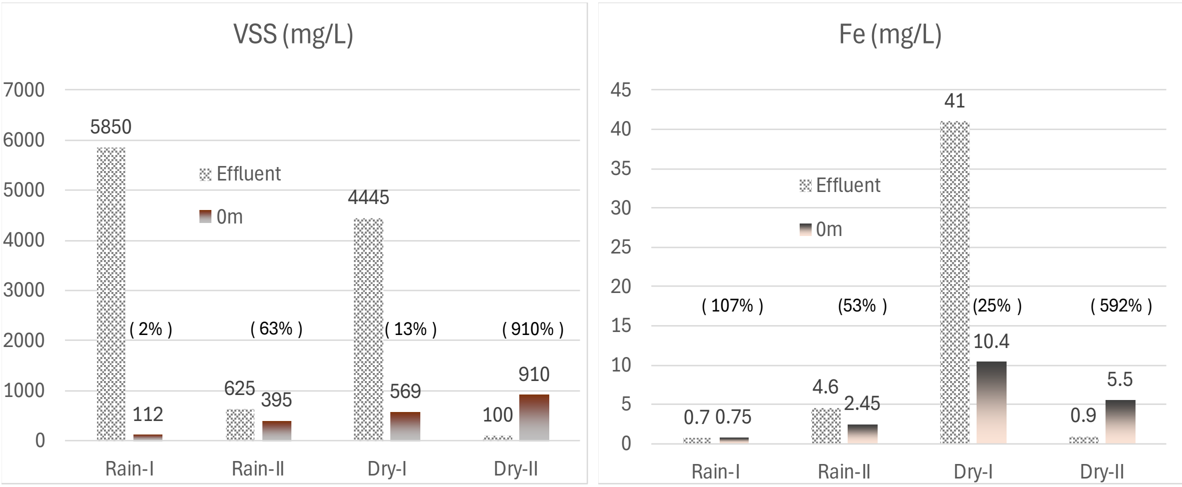
Effluent in the WTP is greatly affected by sludge from sedimentation tanks and backwash water from filtration tanks, and its concentration fluctuates greatly because it becomes highly concentrated during desludge and low in turbidity during backwash. Turbidity, TSS, VSS, Fe, etc. are significantly detected in Effluent at high concentrations, often reaching levels that cannot be compared to river water.

After leaving the WTP, the effluent is discharged into the Bassac River 1.6 km away from the WTP, mixing with miscellaneous domestic wastewater and rainwater runoff from the surrounding area. This is the "0m" point called in this Effluent Impact Study. A comparison between the Direct Effluent and the 0m point is shown in **Figure 4-1** and **Figure 4-2** to illustrate the changes between the WTP and the discharge outlet.



Source: JST

Figure 4-1 Comparison between Effluent and 0m Point (1)



Source: JST

Figure 4-2 Comparison between Effluent and 0m point (2)

As described above, it is presumed that the extremely fluctuating high - low concentration effluent is homogenized and/or diluted during the 1.6 km discharge channel, and the peak seen in the effluent disappears at the 0 m point, the range of fluctuation decreases and becomes relatively stable.

2) TSS

The results of the survey in the Bassac River identified the following trends.

<< Rainy season >>

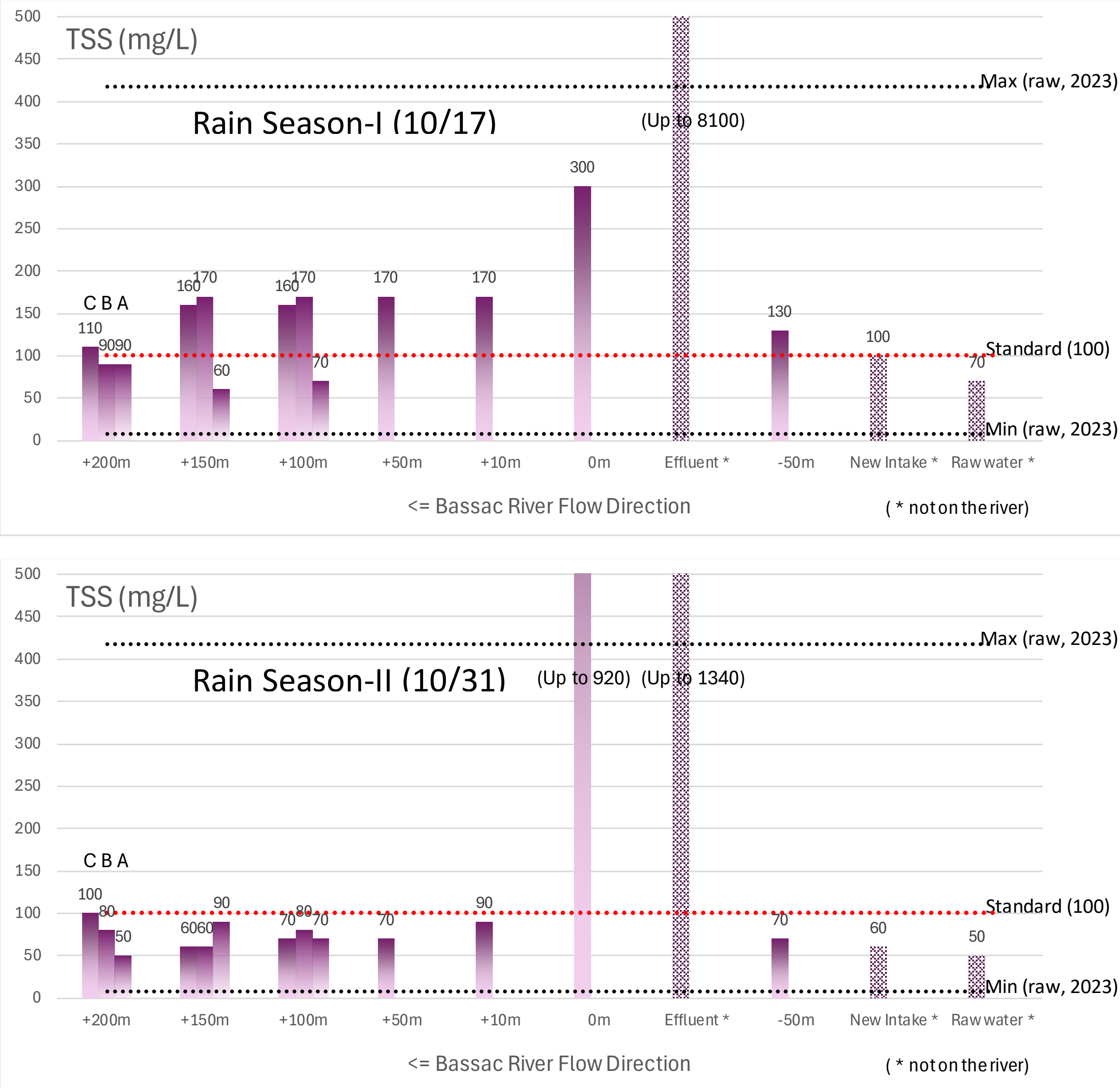
- In the first survey during the rainy season, the value already exceeds the standard at -50m, and the concentration was higher at 0m, but diffused and diluted downstream. Relatively high concentrations are also found at the +150m point.
- In the second survey during the rainy season, the values do not exceed the standard at all points, and although high concentrations are observed at the 0m point, they rapidly decrease at the +10m point, and no effect of discharge is observed thereafter.

<< Dry season >>

- In the first survey during the dry season, the values exceeded the standard only at the 0m and +10m points, and no effect of effluent discharge was observed downstream.
- The results of the second survey during the dry season was similar, with high concentrations observed at the 0m and +10m points, but no effects were observed downstream.

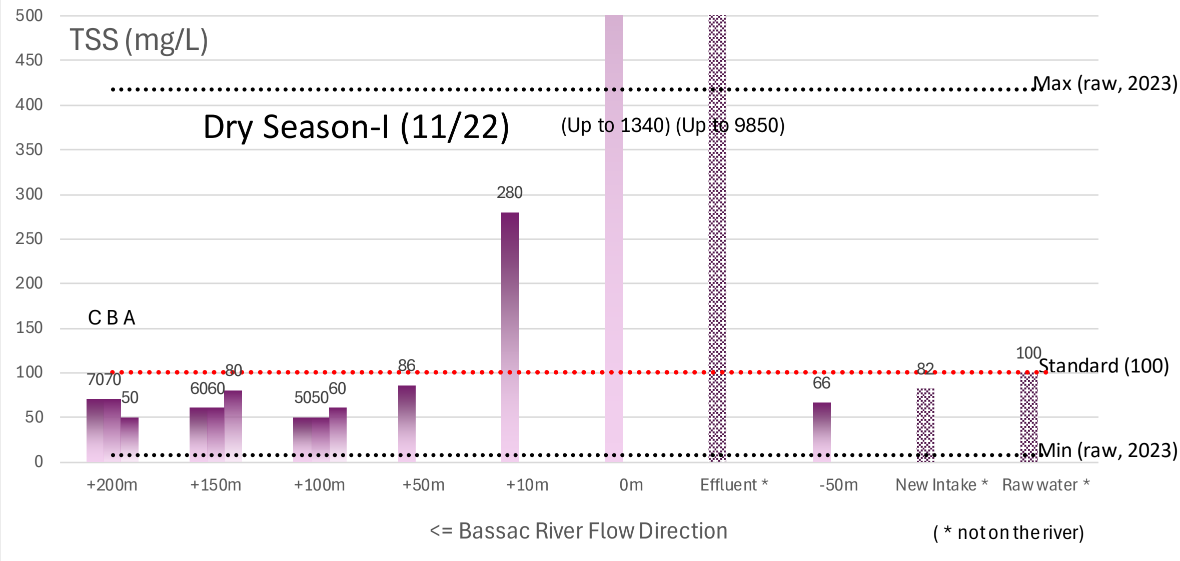
Overall, the results indicated that although the effluent discharge resulted in locally high concentrations, they were diffused and diluted downstream, and the impact was limited.

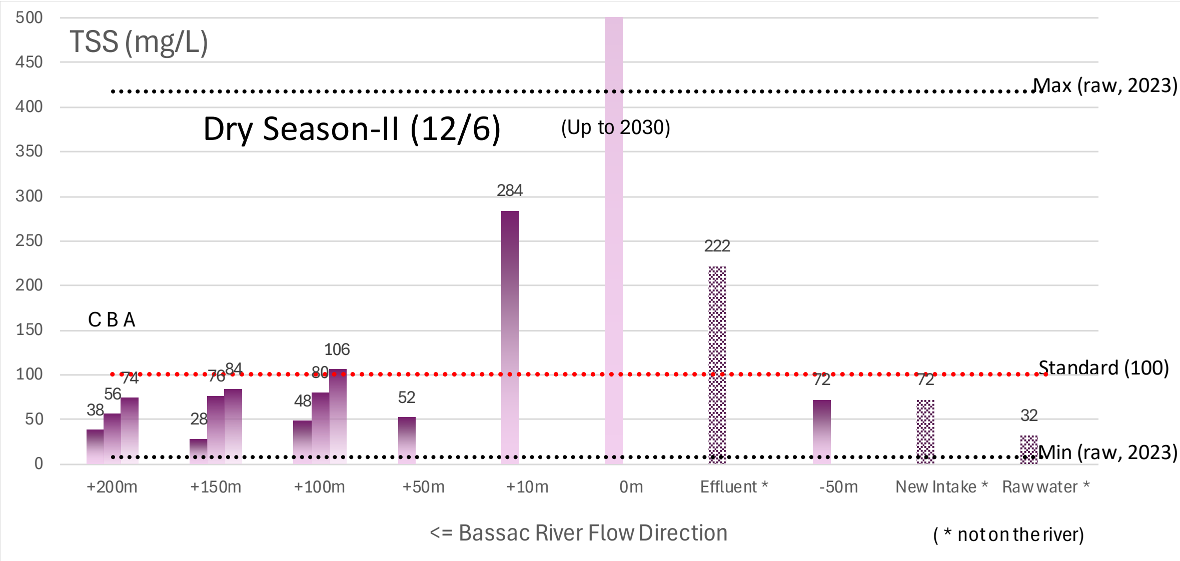
The distribution of TSS in raw water from the WTP (Mekong River) in 2023 was in the range of 7 to 417 (mg/L) as shown in **Figure 4-3** and Figure 4-4, and was within the same range at each point of the Bassac River at the time of this survey, except at the 0m point.



Source: JST

Figure 4-3 TSS Measurement Results (1)





Source: JST

Figure 4-4 TSS Measurement Results (2)

3) Fe

The results of the survey of iron (Fe) concentrations in the Bassac River confirmed the following trends.

<< Rainy season >>

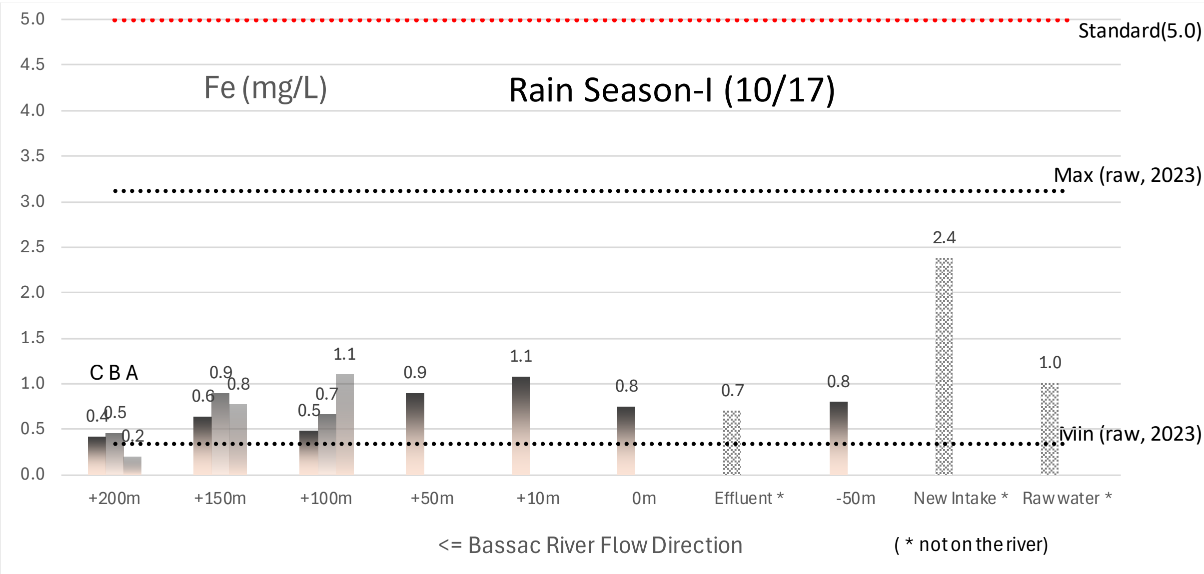
- In the first survey during the rainy season, Fe concentration remained below the effluent standard (5 mg/L). The concentration was slightly high at 2.4 mg/L at the New Intake site on the Mekong River, but this is not considered to be a unique situation. Similar values have been recorded in the past, suggesting the possibility of iron fluctuations.
- In the second survey of the rainy season, the effluent (4.6 mg/L) was close to the standard value, and 2.5 mg/L was also recorded at the 0 m point. The effect of effluent discharge is suspected, but it is not considered to be particularly abnormal within the range of past measurements.

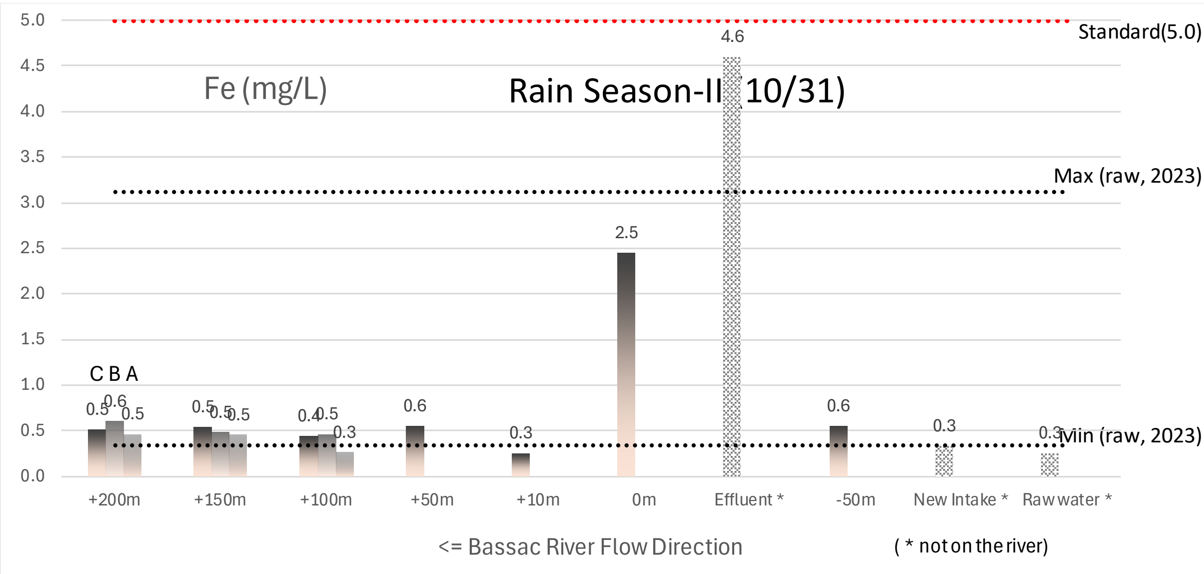
<< Dry season >>

- In the first survey during the dry season, the values with 41 mg/L at Effluent and 10.4 mg/L at the 0 m point exceeded the standard. Slightly higher concentrations continued at downstream sites, indicating the influence of effluent discharge. However, with the exception of the 0m point, where concentrations were particularly high, they fall within the measurement range for 2023.

- In the second survey during the dry season, the value of 5.5 mg/L exceeded the standard at the 0 m point, but downstream, the impact was limited and the influence of effluent discharge could not be determined.

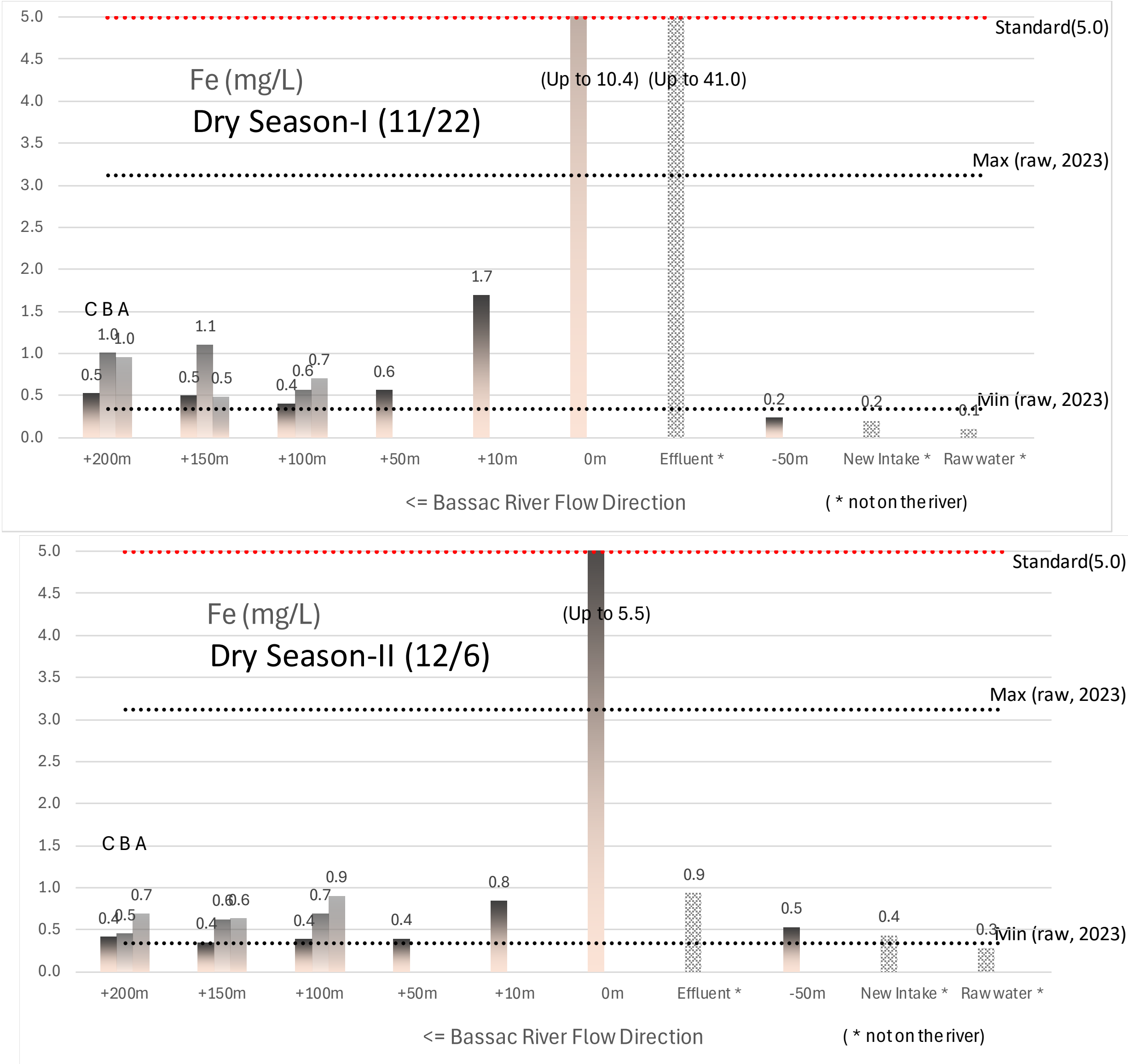
Overall, although exceedances of the standard were observed in Effluent and at the 0-m point, concentrations decreased downstream, and no widespread serious impacts were identified.





Source: JST

Figure 4-5 Fe Measurement Results (1)



Source: JST

Figure 4-6 Fe Measurement Results (2)

4) Property items（pH、VSS、TDS、BOD、COD、DO）

The pH values were within the effluent standard range of 5.5 to 9.0 at every point of all surveys, and no major fluctuations were observed, and no particular problems were identified, including effects on the discharge destination.

The results of the VSS survey confirmed the following trends

<< Rainy season >>

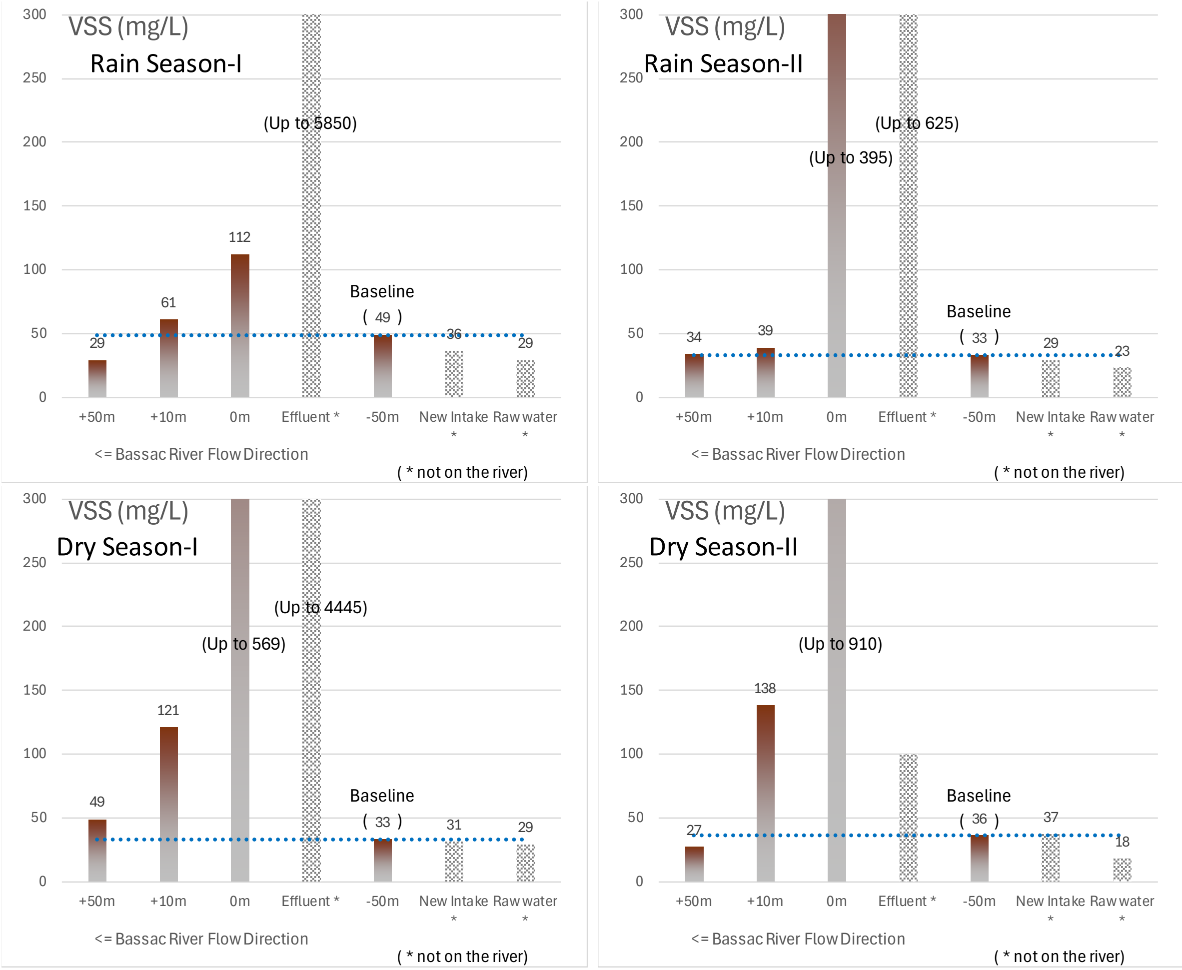
- In the first survey during the rainy season,, the concentration exceeded the baseline at the 0m point, but decreased downstream, confirming dilution and diffusion.
- In the second survey during the rainy season, high concentration (395 mg/L) was observed at the 0 m point, but it decreased to the baseline level downstream, confirming the effect of dilution and diffusion.

<< Dry season >>

- In the first survey during the dry season, the decrease in concentration at +50 m was smaller than in the second survey during the rainy season, suggesting a decrease in dilution and diffusion effects due to the decrease in flow rate.

- In the first survey during the dry season, the concentration was high at 0 m but it was below the baseline at +50 m, suggesting that the lack of decrease In the first survey during the dry season was temporary.

Overall, dilution and diffusion downstream was observed during the wet season, while the dry season was affected by the flow reduction, but was judged to be temporary.



Source: JST

Figure 4-7 VSS Measurement Results

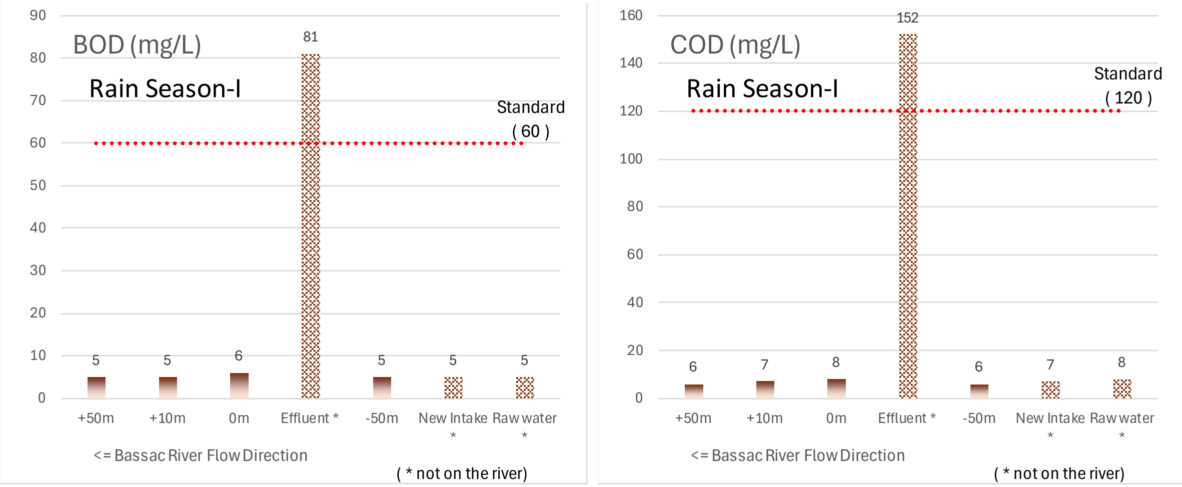
The results of the first survey during the rainy season showed little change in TDS values other than effluent, and no other discharging effects were observed. However, the results of the second survey during the rainy season, the first and second survey during the dry season showed effluent discharge effects at the 0 m point. On the other hand, no significant effects were observed further downstream.

The results of the BOD and COD surveys are as follows:

- In the first survey during the rainy season, exceedance of the standard value was observed in the effluent, but in the river, the concentration was below the standard value at all sites, and no effect of effluent discharge was observed.
- In the second survey during the rainy season, and in the first survey during the dry season,an increase in concentration was observed at the 0 m site, but the effect was not noticeable at the +50 m site and was below the standard value.

- In the second survey during the dry season, there was a small decrease in concentration at 0 m and +10 m, but at +50 m the impact was limited and below the standard value.

Overall, the effluent locally increased BOD and COD, but downstream the impact was small and no exceedances of the standard were observed.



Source: JST

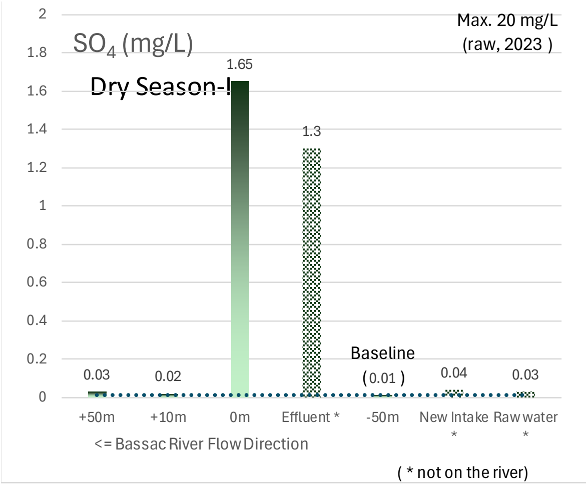
Figure 4-8 BOD･COD measurement results

The dissolved oxygen (DO) levels were well above the effluent standard value of 4 mg/L at all survey points, and no particular problems were observed. 0 m, where VSS levels were relatively high, did not show a clear decrease, and the organic pollution situation in the river near the survey points was not remarkable. In addition, although a slight decrease was observed in the effluent, the difference was not significant, and no effect of effluent discharge was observed.

5) Nutrients, etc.（NO_3、PO_4、T-N、T-P、SO_4）

The results of all surveys showed no exceedances of effluent standards for nutrients (NO_3, PO_4, T-N, and T-P) at any of the sites. Generally, values were well below the standard, and there was no significant increase in concentrations at the 0-m point, indicating that the effluent discharge had no impact.

Concerning SO_4, the concentration at 0m was slightly higher than that at -50m in the first and second survey during the rainy season and the second survey during the dry season, but further downstream, the concentration decreased to the baseline level. Furthermore, when compared to the maximum concentration of 20 mg/L in raw water from the Nirodh WTP in 2023, it is sufficiently low, and no clear impact on the discharge destination due to the effluent is observed. In the first survey during the dry season, changes were observed, and significantly higher values were found in the effluent and at the 0m point compared to other points. However, the concentration was sufficiently low compared to past raw water concentrations, and there was no clear impact on the destination of the discharge.



Source: JST

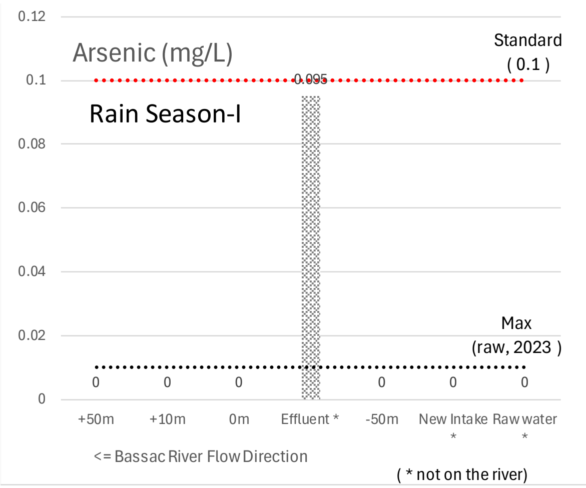
Figure 4-9 SO_4 Measurement Results

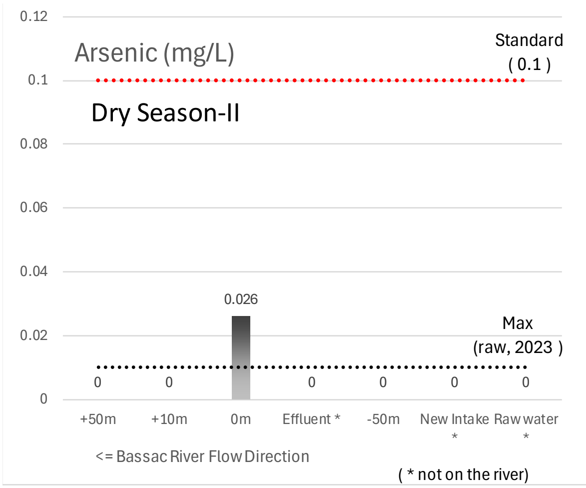
6) Metals（As、Hg、Al、Mn）

As a result of the first survey during the rainy season, arsenic (As), a heavy metal, was detected[2] at 0.095 mg/L, close to the effluent standard (0.1 mg/L) in the effluent.

The results of the second survey during the rainy season and first survey during the dry season showed that arsenic was not detected at any point, but the results of the second survey during the dry season showed that 0.026 mg/L was detected at the 0 m point. This corresponds to 26% of the standard value.

On the other hand, since it was not detected at any of the downstream sites, there was no change in the quality of the water at the discharge site.





Source: JST

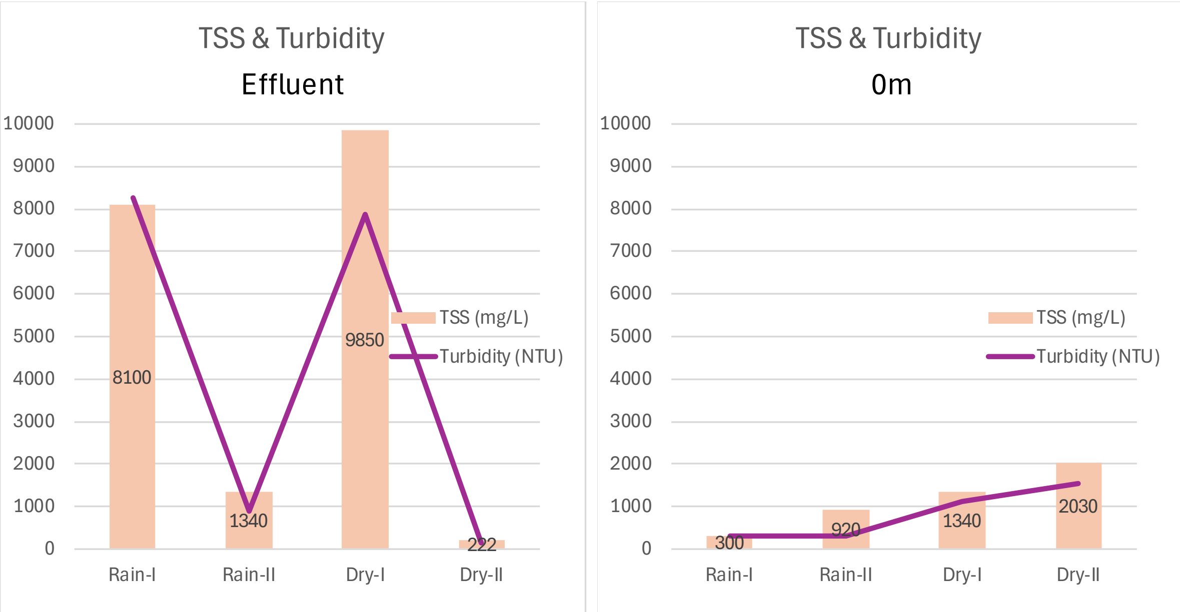
Figure 4-10 As Measurement Results

The results of the arsenic measurement confirm the following points.

- Arsenic is a heavy metal with high specific gravity and is often derived from turbidity.

[2] The detection limit of As is 0.002 mg/L with the testing method as ISO 17378 (hydride generation atomic fluorescence spectrometry). For reasons of space limitation, this is indicated as '0' in the diagram.

- In the first survey during the rainy season, arsenic was detected in the effluent when the TSS was 8,100 mg/L, but not when the TSS was 9,850 mg/L. This indicates that arsenic may not be detected even at high turbidity depending on the raw water quality.
- In the second survey of the dry season, arsenic was detected at 0 m at 0.026 mg/L. Although TSS was low at 2,030 mg/L, it is not considered abnormal because arsenic of 0.01 mg/L can be detected in raw water and is concentrated during water treatment.
- It is assumed that arsenic may have precipitated in the discharge channel, and arsenic may be detected even at low TSS due to being pushed out by the momentum of the effluent.
- Overall, the results suggest that arsenic detection is not necessarily proportional to TSS concentration and is affected by conditions in the raw water and discharge channel.



Source: JST

Figure 4-11   TSS/Turbidity Measurement Results

-

Mercury (Hg) was not detected at any of the sites during all surveys.

Aluminum (Al) was not found to be affected by the effluent discharge, as the maximum concentration in raw water in 2023 exceeded 2 mg/L, where the observed concentration is sufficiently low in comparison, and no values exceeding the baseline were observed.

The concentration of Manganese (Mn) was sufficiently low compared to the effluent standard at all sites during all surveys, and no consistent trend was observed, so the effect of effluent discharge cannot be confirmed.

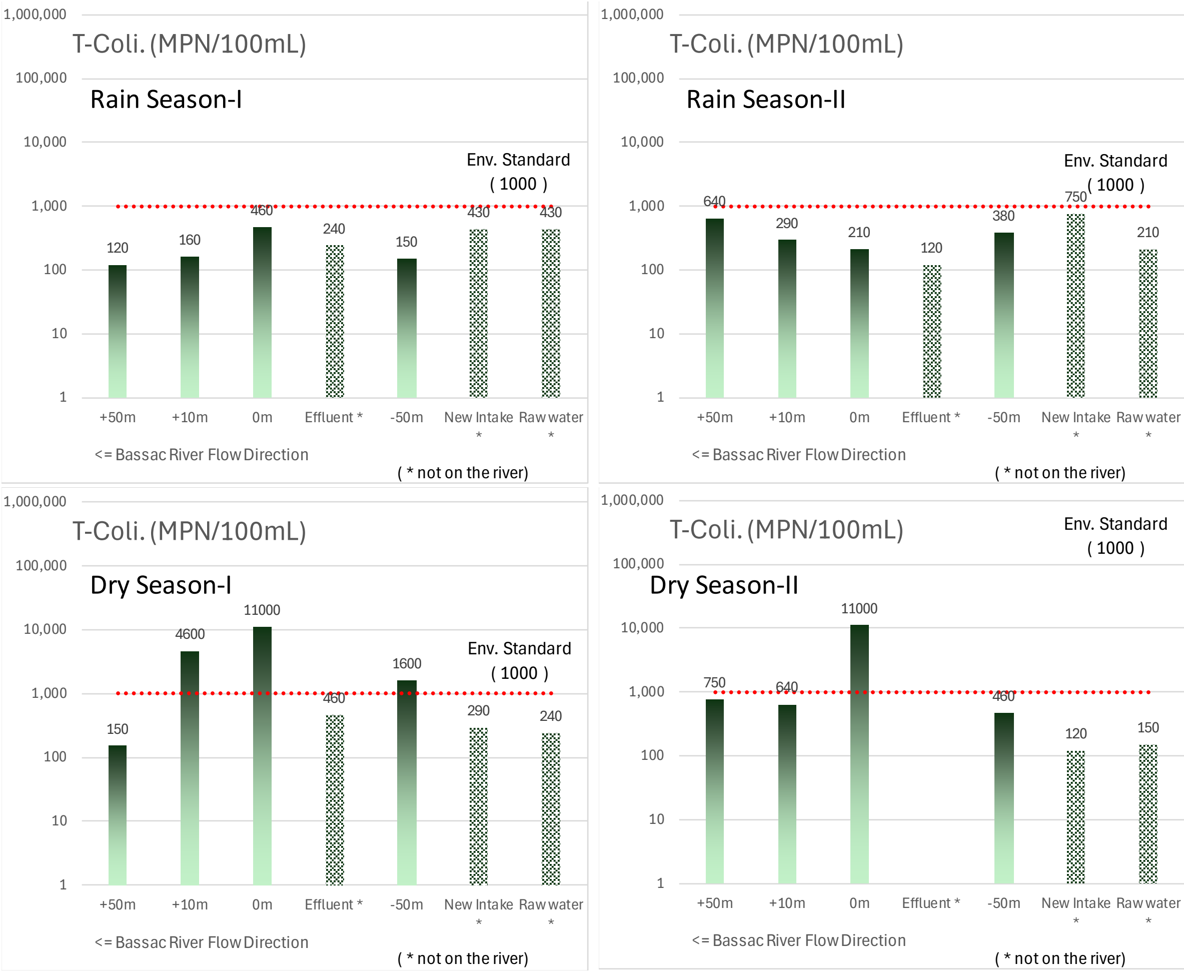
7) Others (total coliform, residual chlorine, oil or grease, detergent)

The results of total coliform survey are as follows:

- In the rainy season, both the first and second surveys were generally below the environmental standard value (1000 MPN/100 mL, no discharge standard is set). However, higher values were observed in the river than in the effluent, suggesting that growth in the environment may have affected the results.

- A change was observed during the dry season, with the standard value being exceeded at three points in the river in the first survey during the dry season and at the 0 m point in the second survey during the dry season.
- There were no exceedances of the standard in effluent, and it was determined that the exceedances were not due to effluent from the WTP, as the upstream points and other domestic wastewater influent were likely affected.

Overall, the results indicated that the increase in coliforms was largely influenced by the season and the surrounding environment, and was not mainly caused by the effluent from the WTP.



Source: JST

Figure 4-12 Total Coliform Measurement Results

Residual chlorine was not detected at any of the sites.

Oil & grease and surfactants (detergent) were not detected at any of the sites in all surveys.

8) Summary of survey results

From the results of the survey presented above, it is clear that;

➢ The effluent from the Nirodh WTP consistently exceeds TSS compared to effluent standards, and

BOD, COD, and iron (Fe) can also be exceeded.

- At 0m, the influence of effluent discharge is clearly observed based on comparison with values upstream and downstream.
- For iron (Fe), changes in water quality downstream were observed. TSS and VSS may also cause water quality changes downstream.
- No downstream water quality changes have been observed for arsenic and mercury, which have been pointed out to be particularly toxic.
- Considering the comparison with the effluent / environmental standard values and the range of water quality fluctuation based on the historical data of the surrounding rivers, no abnormal values were confirmed for all items measured this time except for the 0m point on the river.

The above shows that the effluent discharged from the Nirodh WTP exceeded the effluent standard for some items, and the water quality at the discharge outlet (0 m point) after passing through the 1.6-km discharge channel clearly shows these characteristics. In addition, water quality of items such as iron changed downstream as a result of effluent discharge.

On the other hand, highly toxic substances were not detected except in the effluent and at the discharge outlet, and no abnormal water quality changes were observed for other items at the discharge destination.

Therefore, it was not possible to identify any adverse effects of the effluent from the Nirodh WTP on the discharge site.

5. Discharge Plan

Based on the results of the above mentioned studies, the following are future measures regarding effluent discharge that should be implemented as the WTP.

- Plan discharge to adjust frequency and timing, and conduct operations that do not adversely affect current discharge conditions.
- Reduce environmental impact through operations that control the concentration of sludge, which has a particularly large impact.

Discharge conditions

The discharge conditions currently being operated at Nirodh WTP Phase I and II and those planned for Phase III, which is scheduled for construction, are as follows

【Amount】

Nirodh-WTP Phase I and II (existing): 12 + 12 water treatment systems

Nirodh-WTP Phase III (planned): 18 water treatment systems

Total: 42 systems

<< Phase I and II >>

<u>Backwash (from sand filter)</u> water: 3094 m^3/day average in 2023 (129 m^3/day per system), 420 m^3/30min/time average in 2023 (per system)

<u>Desludge (from sedimentation tank)</u>: 1318 m^3/day (54.9 m^3/day per system), 2.29 m^3/min (per system)

<< Phase III >>

Estimated backwash water: 2320 m^3/day (129 m^3/day, 420 m^3/time per system)

Estimated desludge: 988 m^3/day (54.9 m^3/day, 2.29 m^3/min per system)

【Frequency】

<< Phase I and II >>

Backwash: 113 times per system average in 2023 (every 3.2 days per system)

Backwash: 7.4 / 24 systems per day

Desludge: 1 minute per hour, 24 times per system daily, 576 times in total daily

<< Phase III >>

Estimated backwash: 113 times per system, 5.6 / 18 systems per day

Estimated desludge: 1 minute per hour, 24 times per system daily, 432 times in total daily

<< Phase I, II and III >>

Backwash: 13 / 42 systems per day

Desludge: 24 times per system daily, 1008 times in total daily

Discharge plan

The discharge conditions of Phase I and II in operation under the above discharge conditions are summarized and the proposed discharge plan for Phase III is proposed as follows.

【Amount】

Backwash: 420 m^3/30min = 0.23 m^3/s/system

Desludge: 2.29 m^3/min = 0.038 m^3/s/system (x 42 systems =1.60 m^3/s)

Nirodh-WTP Effluent Capacity = 1.16 m^3/s

The total discharge capacity of the WTP may be exceeded if Desludge with a large total volume is duplicated and flowed simultaneously. Fortunately, since each discharge is operated for one minute, overcapacity will not occur if the systems are flushed in sequence at 0.038 m^3/s each.

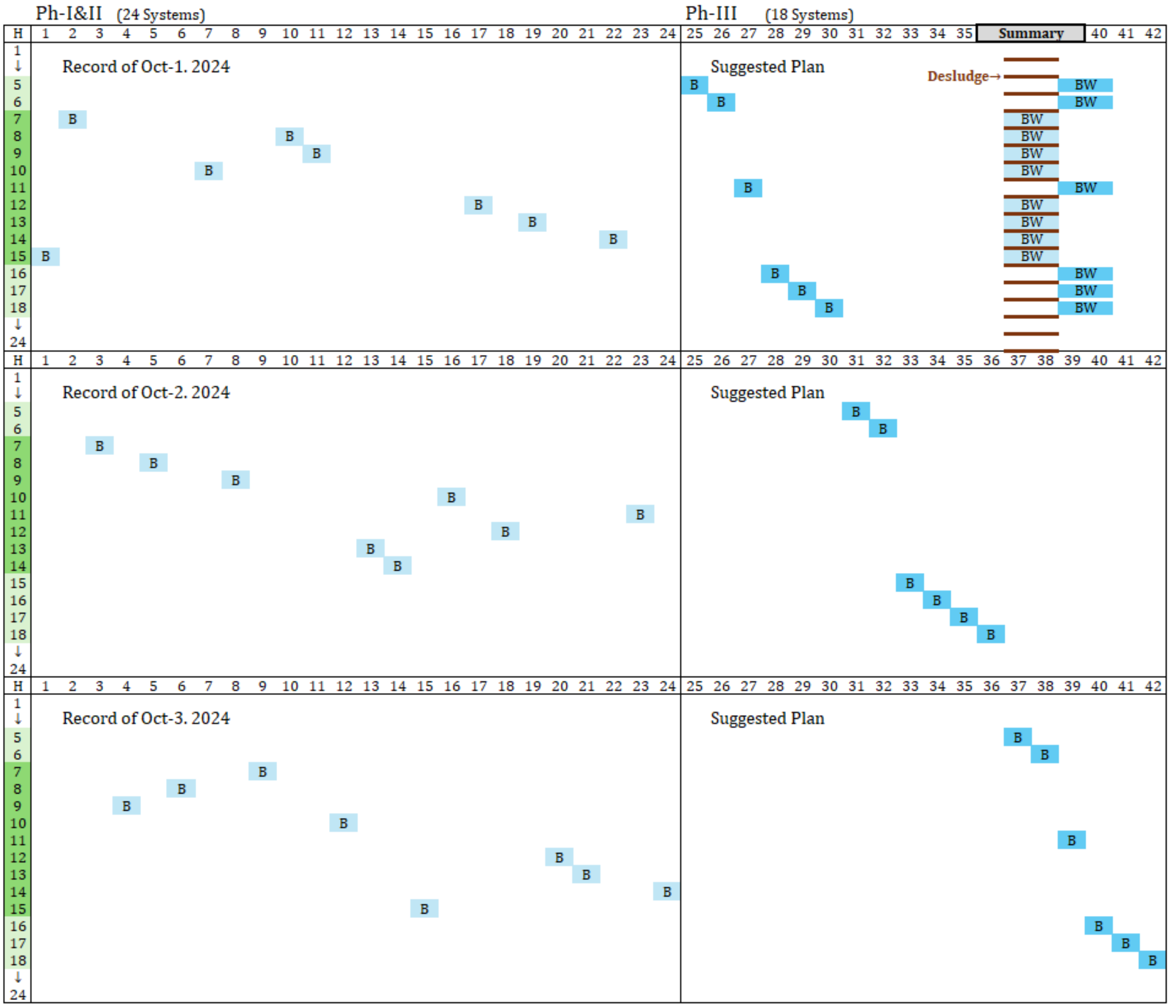
【24 hours x 3 days discharge plan】

Below are the current operating results for Phase I and Phase II and the proposed discharge plan for Phase III.

The example of backwash on October 1-3, 2024, is planned so that there is no overlap of the 24 systems over a 3-day period, one system at a time.

A similar discharge plan with the addition of the 18 systems in Phase III, for example, would be as follows: given the dilution effect of the Desludge that continues to occur 24 hours a day, it is preferable to do Backwash before, after, or in between existing operations (see “Summary” in the figure).

Note that all Backwash on October 1-3 is conducted from 7am-3pm, but unless there is a particular problem, the main operation is automatic and can be conducted 24 hours a day, 7 days a week. Even if nighttime operation is avoided, it can be kept within the 5am-6pm time frame.



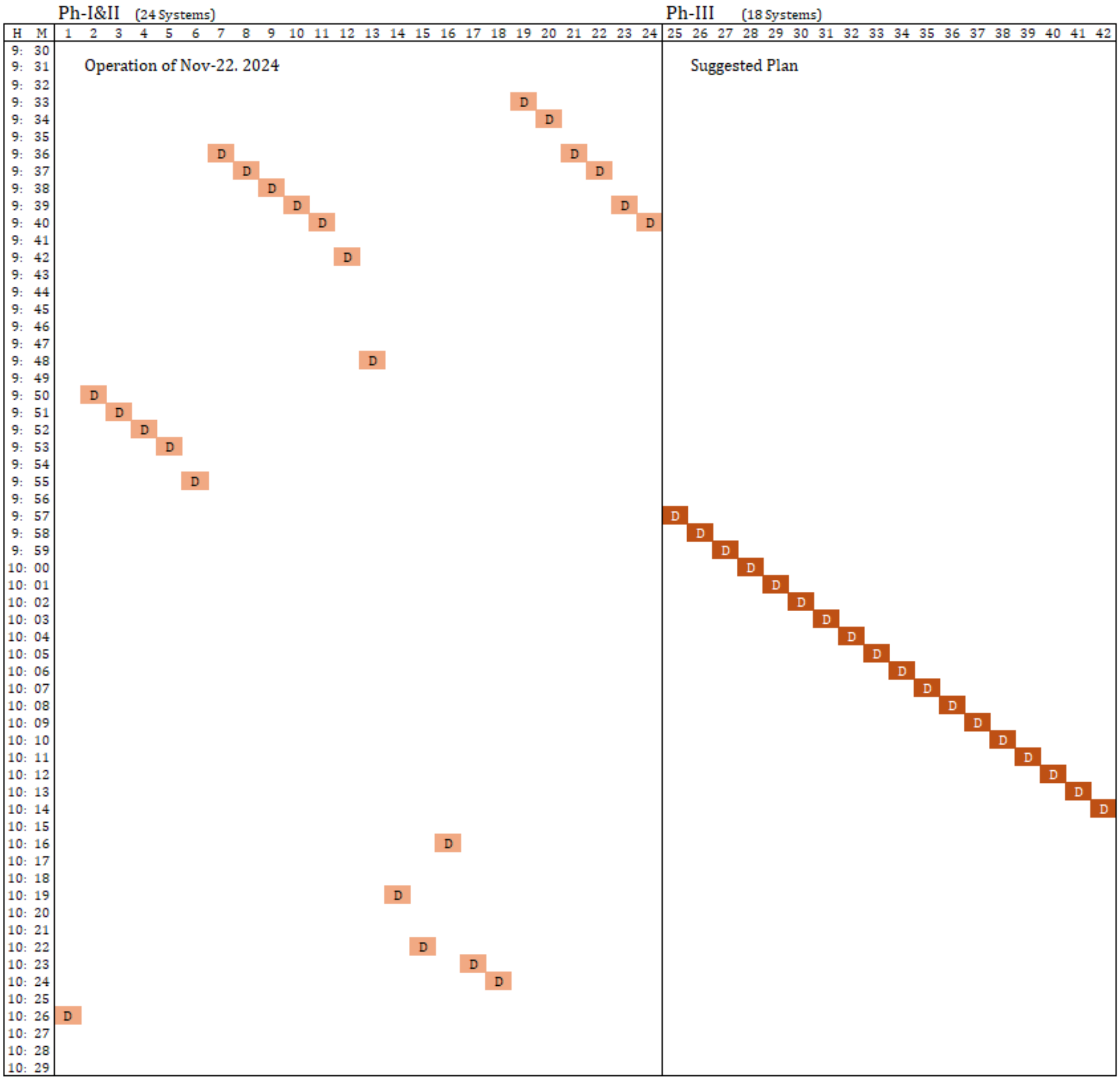
Source: JST

Figure 5-1 Discharge Operation and Proposed Plan（Backwash）

Below are the current operating results of Desludge in Phase I and Phase II and the proposed plan for Phase III.

On November 22, 2024, Desludge in the example is basically planned to have 24 systems distributed, although there is some overlap.

For example, adding the 18 systems of Phase III and planning a similar operation here would result in the following



Source: JST

Figure 5-2 Discharge operation and proposed plan（Desludge）

As mentioned above, the current discharge plan for both Backwash and Desludge is decentralized, and the addition of Phase III will not cause significant changes if based on a proper plan.

There is also room for consideration of improvement measures such as increasing the frequency of Backwash and Desludge to decrease their respective concentrations and increase the dilution effect.

6. Future Monitoring Plan

In this Study, sampling on only four individual days may miss peak contaminant events, particularly during heavy rainfall or operational irregularities. Continuous monitoring is recommended to better identify variability, especially during desludging and backwashing operations. Auxiliary sampling points were limited to TSS, Fe and turbidity, leaving gaps in the understanding of other parameter distribution across the river. The influence of potential domestic wastewater, particularly at the 0m point, requires further investigation. Sampling lacked continuity, making it difficult to assess short-term pollution spikes.

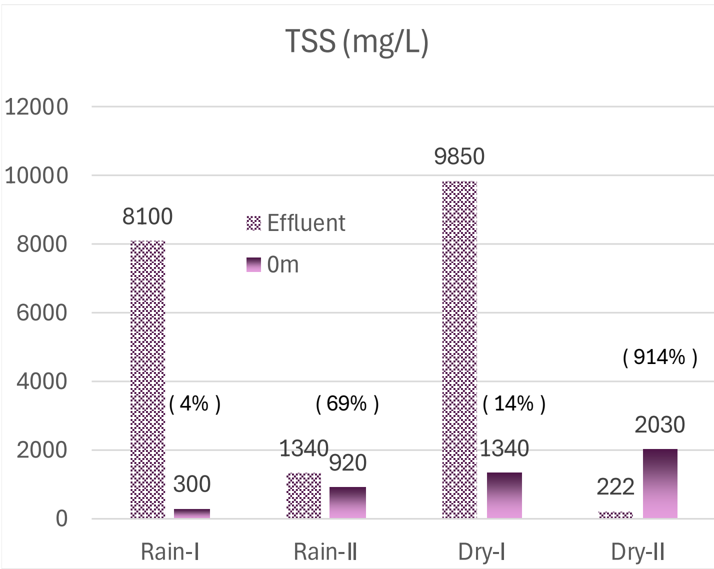
Iron concentrations exceeded effluent standards at the effluent and 0 m points during the dry season. Although levels declined downstream, suggesting natural dilution, the localised impact remains a concern, particularly in the dry season, and requires continued monitoring. Arsenic was detected inconsistently. Although not found downstream, the toxicity and persistence of arsenic highlight the need for long-term observation.

The study also showed that the water quality concentration of the discharged water is sufficiently reduced by the dilution and diffusion effect of the river. On the other hand, As and Fe cannot be overlooked as they are substances that accumulate as sediment in the discharge channel.

The above indicates that water quality monitoring for Cambodia's discharge standard items (including As and Fe) of the discharged water from Nirodh WTP will continue to be monitored under the responsibility of PPWSA as indicated in the Environmental Monitoring Plan attached to the 'Preparatory Survey on Nirodh Water Supply Expansion Project' report.

7. Conclusion

Based on the results of this survey and the discharge management situation described above, we will summarize the TSS concentration as an example with regard to the quality of the effluent in WTP and the water to be discharged to the environment. The measured effluent sample immediately after desludge was 9,850 mg/L (maximum concentration, first survey during the dry season), and the effluent sample during backwash was 222 mg/L (minimum concentration, second survey during the dry season) (**Figure 7-1**).



Source: JST

Figure 7-1 Variations in TSS before and after Discharging

The TSS of sludge with 99% water content was estimated from the raw water TSS of Phase I and Phase II currently in operation as follows, and since there is no significant difference from the actual measured values, it is considered that the results of this Effluent Impact Study have a typical range of effluent quality fluctuation.

【Maximum TSS calculated value for effluent】

Backwash: 173 TSS mg/L

Desludge: 10,011 TSS mg/L

On the other hand, the range of TSS at 0 m in the Bassac River is 300 to2,030 mg/L, suggesting that TSS is homogenized in the 1.6 km discharge channel from the Effluent sampling point to the 0 m point and is approaching the average value, with a smaller range of variation than in the Effluent.

Desludge with higher TSS has less water amount, while Backwash with lower TSS has more amount, and thus TSS decreases significantly when mixed. Based on the maximum and minimum TSS values obtained in this Effluent Impact Study and the operating conditions (9:30-10:00, Nov-11, 2024), the mixed effluent TSS of Desludge and Backwash can be estimated as follows.

【Mixed effluent TSS calculation】

Backwash: 420 m^3/30min (1 time)

Desludge: 2.29 m^3/min (18 times)

Backwash: 222 mg/L x 420 m^3 = 93,240 g

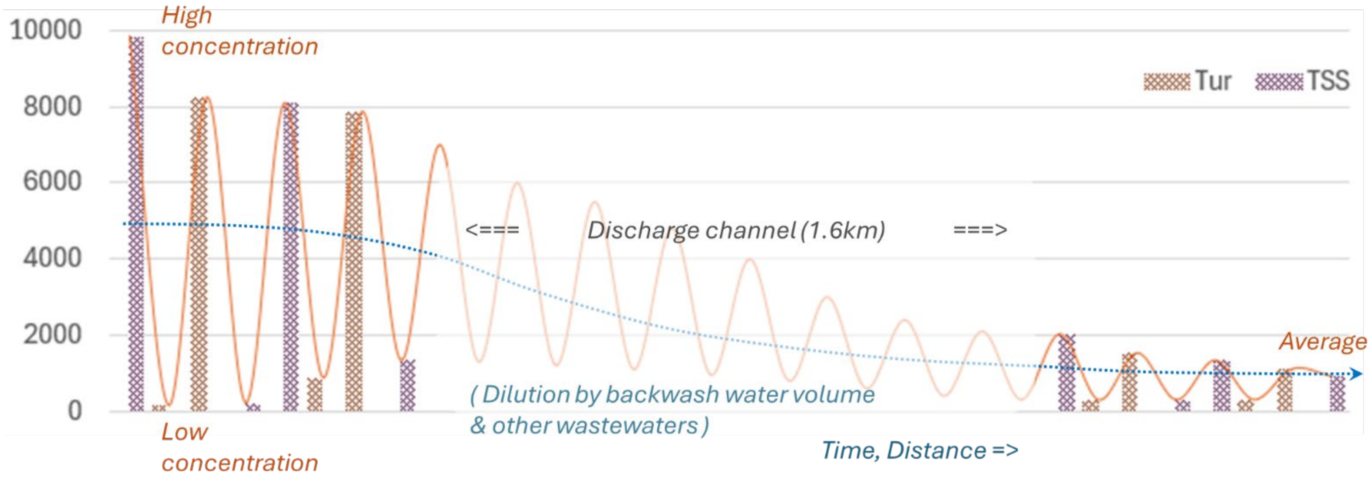
Desludge: 9,850 mg/L x 2.29 m^3 = 22,557 g

Desludge: 22,557 g x 18 times = 406,026 g

Mixture: [93,240 + 406,026 (g)] / [420 + (2.29 x 18) (m^3)]

Mixture: = 499,266 / 461.22 = 1,082.5 (g/m^3) = 1,082.5 (mg/L)

The TSS concentration at the 0m point shown in **Figure 7-1** is higher and lower than the calculated mixed effluent TSS value of 1,083 mg/L. This suggests that homogenization is in progress at the 0m point. In addition, since other wastewater influent from the surrounding area flows into the discharge channel, it is assumed that the dilution effect of the wastewater is also occurring. Assuming this situation, an image of homogenization and dilution in the discharging channel is created in **Figure 7-2** (the bar chart is based on the measurement results, but the curve for the middle part of the channel is drawn based on assumed values).



Source: JST

Figure 7-2 Image of Homogenizations and Dilution in the Discharge Channel

Therefore, by maintaining the existing drainage management approach, this project will continue to homogenize and dilute high-concentration wastewater in the drainage channel to stabilize water quality. As a result, even with the expansion and operation of Phase III, no significant impact on the discharge destination is anticipated.

Furthermore, as outlined in **4.8)**, while certain parameters, such as iron, have shown water quality variations downstream due to wastewater discharge, no abnormal changes were observed for other parameters containing highly toxic substances. The dilution and dispersion effects of the Bassac River were clearly observed, and no adverse impacts on the discharge destination were identified.

Additionally, the content and conclusions of this Effluent Impact Study have been reviewed and validated by experts in the field of water quality engineering, including Professor Daisuke Sano and Associate Professor Amarasiri Mohan of the Environmental Water Quality Engineering Laboratory at Tohoku University, Dr. Chanthol PENG and Dr. Kimleang Khoeurn of Water and Environment, Research and Innovation Center at Institute of Technology of Cambodia.

Accordingly, the conclusions presented in this study serve as a fundamental condition for ensuring the viability of this project.

Finally, a stakeholder meeting was also held on 24 April 2025 to disclose the results and review of this study to the residents living near the discharge channel and outlet. As a result, the participants expressed no objection and social agreement was obtained.

ANNEX 7 ALTERNATIVE SURVEY

1. Outline of Comparative Study

This document examines alternative routes for the water transmission pipeline plan and alternative options for wastewater and sludge treatment at the water treatment plant. ***Table 1-1*** presents an overview of the project if the alternative options are adopted.

Table 1-1 Outline of the Project (if alternative options are adopted)

Item	Description	
Name of the Project	Nirodh Water Supply Expansion Project	
Object of the Project	To contribute to the improvement of the living conditions of people in the Greater Phnom Penh area by expanding Nirodh WTP and supply safe and stable clean water to the area.	
Outline of the Project	As of Kick-off Meeting on Inception Report held on 25th May 2023	As of Meeting on Draft Final Result held on December 2024
	1) Construction by the Contractor ・ Construction of Water Treatment Facility (130,000 m^3/day), ・ Raw Water Transmission Main (Approx. 2 km).	**1) Construction** ・ Construction of Nirodh Water Treatment System, ➢ Facility for Phase III (200,000 m^3/day) including SCADA System, Resource recovery facility, ➢ Construction of Hypochlorite System for Nirodh WTP Phase I~III, ➢ Procurement and Installation of Water Quality Analysis Equipment (1 set), and ➢ Procurement and Installation of Raw Water Pump (1 pump). ・ Construction of Raw Water Transmission Main (approx. length of 2.0 km) ・ Construction of Clean Water Transmission Main from Nirodh WTP to Bassac River Crossing (approx. length of 14 km, open-cut), and ・ Installation of the water transmission pipeline (approximately 0.6 km) using trenchless methods from the water treatment plant to the crossing of National Road 1. ・ River Crossing by Trenchless Method (1 location, approx. length of 0.6 km).
	2) Procurement of Materials ・ Transmission Main (Approx. 40 km), and ・ Distribution Main (Approx. 95 km).	**2) Procurement of Materials and Equipment** ・ For Transmission Pipe (Approx. 20 km), and ・ For Distribution Pipes (Approx. 1320.0 km). ・ Pipes, Fittings, and Equipment for the Establishment of DMA monitoring system
	3) Construction by PPWSA ・ Construction of Pipelines.	**3) Installation of Pipes by PPWSA** ・ For Transmission Pipe (Approx. 20 km), and ・ For Distribution Pipes (Approx. 1320.0 km). ・ Establishment of DMA monitoring system (piping and chamber construction at 10 DMA Entrance)
	4) Consulting Service ・ Review of Outline Design (F/S), ・ Facility Design, ・ Tender Assistance, ・ Procurement of Equipment, ・ Construction Supervision, ・ Support For Improving Maintenance and Management Capacity, ・ etc.	**4) Consulting Service** ・ Review of Outline Design (F/S: this Preparatory Survey), ・ Detailed Design and Supervision for the Installation of Transmission Pipes and Assist to Review BOQ for Distribution Pipes, ・ Tender Assistance, ・ Supervision of Design-Build Works, ・ Assistance for the DX Introduction, ・ Assistance for Capacity Development on Operation and Maintenance.
Target Area	Greater Phnom Penh, Kingdom of Cambodia	
Related Agencies	Implementing and Executing Authority: Phnom Penh Water Supply Authority (PPWSA) Other Agencies: Ministry of Economy and Finance (MEF), Ministry of Industry Science Technology and Innovation (MISTI)	

Source: JICA Survey Team (JST)

As an alternative, a proposal to lay the pipeline along the entire route using existing public roads as the basic plan (described in section 10-2-2) was examined. As a result of the examination, it was confirmed that there are no particular issues regarding land or other matters if this alternative is adopted.

2. Comparative Study on Transmission Pipeline Route

2.1 Outline of Comparative study on transmission pipeline route

The summary of the alternative options for the water transmission pipeline plan is as follows:

Option 1: Water transmission pipeline route requested for examination by PPWSA (described in the main report)
Option 2: Water transmission pipeline route that does not require land acquisition

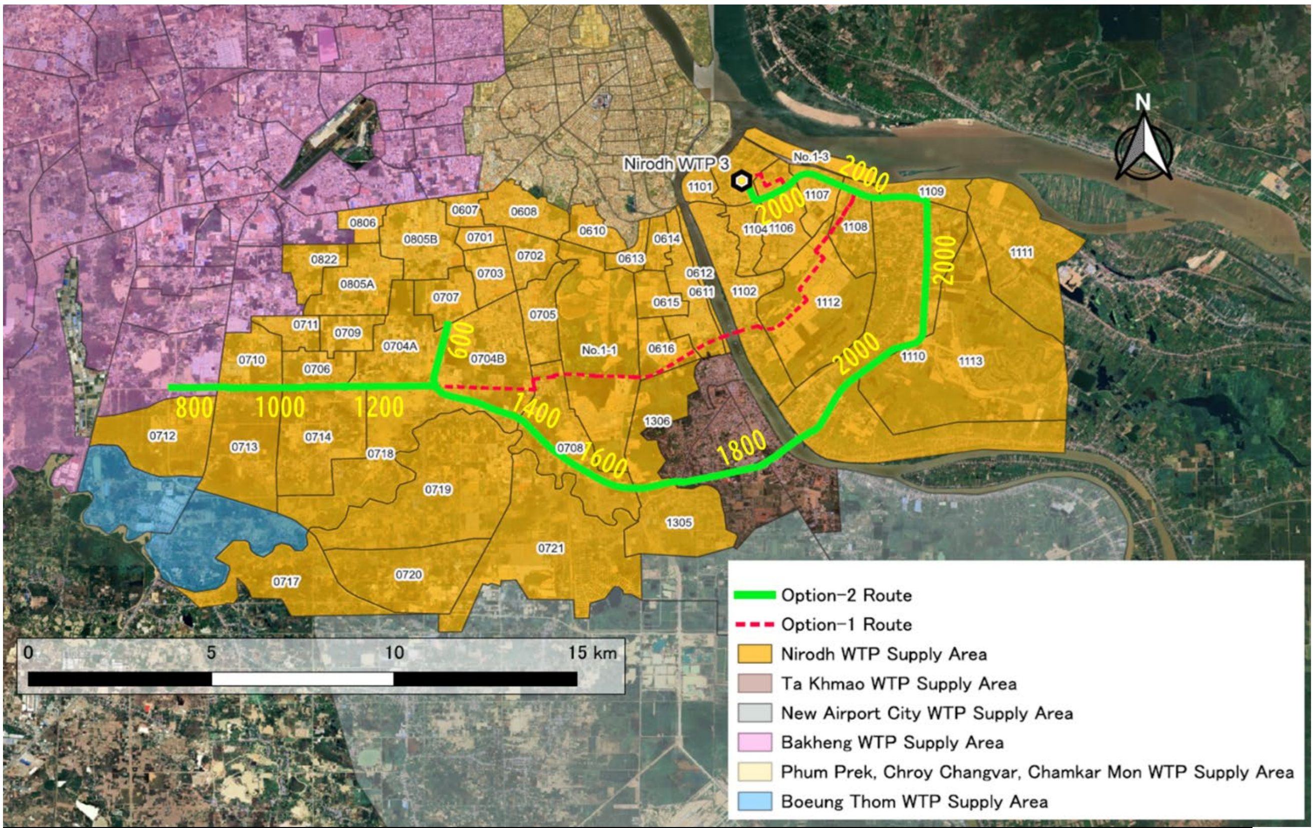
Following discussions with PPWSA, it has been agreed to adopt **Option 1**, the water transmission pipeline route requested by PPWSA.

However, for the implementation of Option 1, it was identified that issues remain regarding obtaining consent from landowners for certain sections, and the acquisition of road land has not been completed. As such, these matters must be resolved prior to the detailed design stage.

This document outlines **Option 2**, the water transmission pipeline route that does not require land acquisition.

2.2 Alternative Transmission pipeline Route

The alternative route for the water transmission pipeline, which does not require land acquisition (Option 2), is shown in ***Figure 2-1***.



Diameter（mm）	Material	Length（km）
600	Ductile Iron Pipe	1.8
800	Ductile Iron Pipe	1.3
1,000	Ductile Iron Pipe	2.4
1200	Ductile Iron Pipe	1.1
1,400	Ductile Iron Pipe	5.0
1,600	Ductile Iron Pipe	5.1
1,800	Ductile Iron Pipe	3.0
2,000	Ductile Iron Pipe	13.5
2,000 （WTP-NR1Crossing、River Crossing）	Coated Steel Pipe for Water Service (Insert pipe 2,000mm) / Sheath pipe (Concrete jacking pipe: 2,400mm)	1.3
Total		34.4

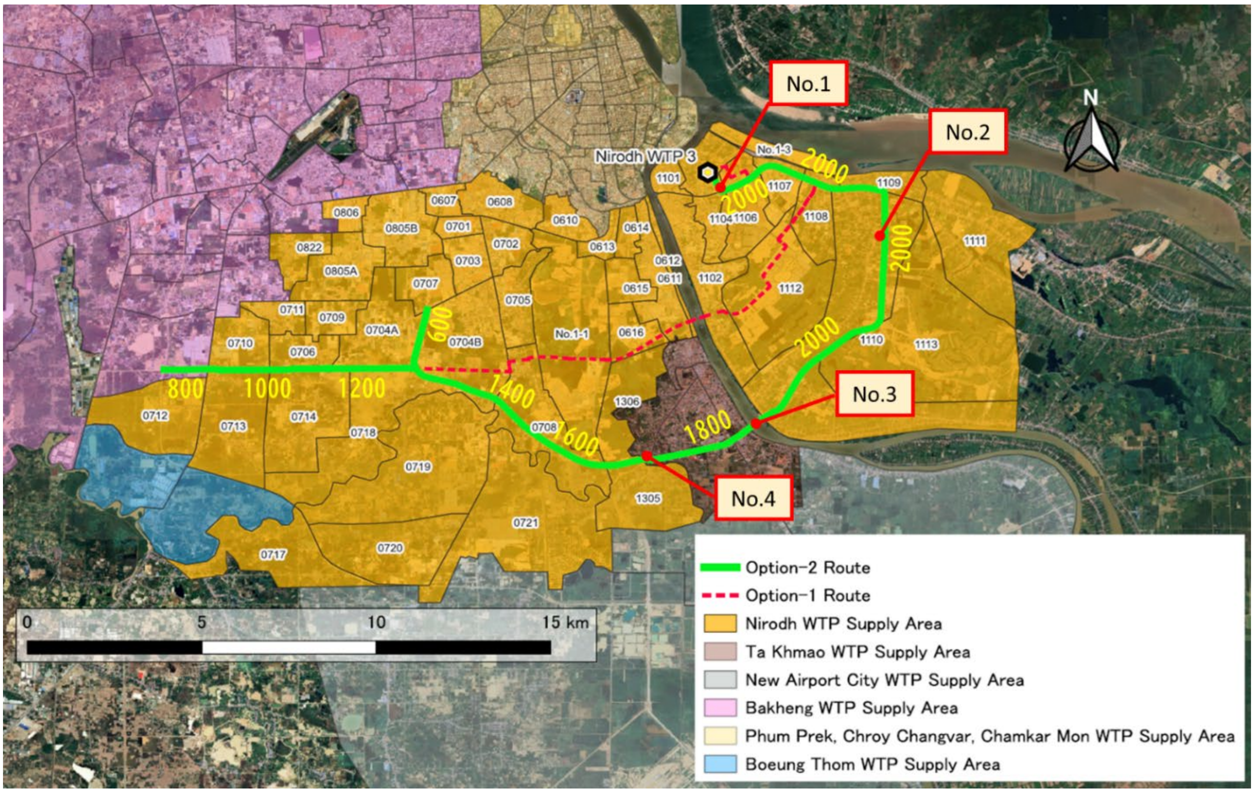
Figure 2-1 Tranmission Pipeline Route Option-2
Source: JST

The alternative route for the water transmission pipeline was designed to follow existing public roads to avoid private land and undeveloped areas. Adjustments were made to ensure that it does not overlap with routes already installed or planned by PPWSA. The transmission pipeline route to the new airport was excluded from this project plan, as it will be considered together with the development of the new water treatment plant for the airport.

Regarding the pipeline diameter, hydraulic calculations have determined that it will range from 600 mm to 2,000 mm. For sections with a diameter of 2,000 mm or larger, as well as sections using the jacking method, only the detailed design will be included in this project. The majority of the construction will adopt the open-cut method.

2.3 Major Crossing Sections of the Alternative Route

The alternative route crosses rivers, canals, and roads. For these crossing sections, discussions were held with PPWSA and relevant authorities to compare and evaluate options such as bridge attachment, pipe bridges, and trenchless methods, in order to propose the most suitable construction method. The major crossing sections and installation methods of the alternative route are shown in ***Figure 2-2***.



No.	Name of River	Transmission Pipe			Installing Method
		Route Number	Diameter (mm)	Length Crossing River (m)	
1	WTP to NR.1	R200-1	2,000	620	Pipe Jacking
2	(Channel)	R200-1	2,000	44	Transmission Pipe Bridge
3	Bassac River	R200-1	2,000	630	Pipe Jacking
4	River Near by Prek Ho Bridge	R160-1	1,600	100	Transmission Pipe Bridge

Figure 2-2 River and Canal Crossing Point
Source: JST

Regarding the route from the water treatment plant to National Road No.1, the owner's consent to install the pipe in private land planned in the Option-1 has not been obtained, and presence of existing raw water transmission main and transmission pipelines along the public road makes open-cut construction difficult due to congestion of underground utilities. Therefore, it was decided to use the pipe jacking method (diameter 2,000 mm/ Sheath pipe 2,400mm).

For the crossing section of the Bassac River (Location No. 3), the plan is to install the pipeline near the existing Ta Khmao Bridge. However, the diameter of the pipe that can be attached to the existing bridge is limited to a maximum of 800 mm. Therefore, a pipe jacking method (diameter 2,000 mm / Sheath pipe 2,400 mm) was adopted. The specifications for the pipe jacking method at the Bassac River crossing (Location No. 3) are presented in ***Table 2-2***.

Table 2-2 Design Condition for the Transmission Pipeline Crossing Bassac River

Condition of Bassac River	Details	
	Crossing Length: 630 m (expected) The deepest point of the river bed: -8.19 m AMSL※1(expected)	
New Facilities to Be Built	**Details**	
Transmission Pipe	Diameter: 2,400 mm Length of Pipe Jacking: 630 m (expected) Method: Slurry Method	
Maintenance Manhole	(1) Driving Shaft	Inner Diameter: 10.0 m (Outer Diameter: 14.0 m) Shaft Depth: 26.0 m Method: Press in Cassion Method Occupation Area : 720 m^2
	(2) Reception Shaft	Inner Diameter: 6.0 m (Outer Diameter: 7.0 m) Shaft Depth: 26.0 m Method: Press in Cassion Method Occupation Area : 500 m^2

※1: The deepest elevation of the river bed is based on the planimetric survey at the location crossing Basac River.
Source: JST

Regarding the pipe jacking method, considering both cost-effectiveness and constructability, it is assumed that a slurry type pipe jacking method will be adopted. For the construction of shafts, since the depth of the shaft is expected to exceed 25 meters, the adoption of a pressed caisson method, which offers good constructability and is relatively space-efficient, is anticipated. Additionally, for the water transmission pipeline, considering the construction experience at the Bassac River crossing, a casing pipe method is assumed. The pipeline will consist of coated steel pipe for water service (Insert pipe 2,000mm) and sheath pipe (Concrete jacking pipe: 2,400mm).

2.4 Hydraulic Analysis of the Alternative Route

The water pressure and flow rate at the entrance of each DMA along the alternative route are shown in ***Table 2-3***.

Table 2-3 Minimum water pressure and daily maximum flow rate at the DMA inlet sections

DMA	Demand (Maximum) (m^3/day)	Elevation (m)	Hydraulic Grade (Minimum) (m)	Pressure (Minimum) (m H2O)	DayMax (m^3/day)
DMA0607	12,091	10.50	43.06	32.56	7,557
DMA0608	35,230	10.50	43.67	33.17	22,019
DMA0610	22,874	8.25	50.01	41.76	14,296
DMA0611	10,718	10.50	55.03	44.53	6,699
DMA0612	1,294	10.49	55.18	44.69	809
DMA0613	11,904	8.26	50.09	41.83	7,440
DMA0614	994	7.00	52.41	45.41	621
DMA0615	10,234	8.00	51.48	43.48	6,396
DMA0616	5,154	6.50	52.35	45.85	3,221
DMA0701	7,838	10.50	45.56	35.06	4,899
DMA0702	1,102	10.50	45.45	34.95	689
DMA0703	24,142	10.50	45.14	34.64	15,089
DMA0704A	13,210	10.76	45.43	34.67	8,256
DMA0704B	13,210	10.50	44.59	34.09	8,256
DMA0705	17,798	10.50	44.64	34.14	11,124
DMA0706	21,934	12.33	43.26	30.93	13,709
DMA0707	10,061	10.50	44.29	33.79	6,288
DMA0708	5,272	9.10	51.07	41.97	3,295
DMA0709	40,712	10.80	41.70	30.90	25,445
DMA0710	2,966	13.80	44.02	30.22	1,854
DMA0711	3,878	12.00	42.73	30.73	2,424
DMA0712	2,258	12.70	46.19	33.49	1,411
DMA0713	3,118	13.00	46.33	33.33	1,949
DMA0714	6,082	12.80	44.71	31.91	3,801
DMA0717	2,606	9.00	41.41	32.41	1,629
DMA0718	5,184	10.50	48.70	38.20	3,240
DMA0719	9,531	9.95	42.48	32.53	1,580

DMA	Demand (Maximum) (m³/day)	Elevation (m)	Hydraulic Grade (Minimum) (m)	Pressure (Minimum) (m H2O)	DayMax (m^3/day)
DMA0720	2,528	9.00	41.92	32.92	5,957
DMA0721	26,146	8.74	38.35	29.61	16,341
DMA0805A	22,451	10.50	42.23	31.73	14,032
DMA0805B	22,451	10.50	42.07	31.57	14,032
DMA0806-1	7,718	10.76	42.91	32.15	4,824
DMA0806-2	7,718	11.65	41.65	30.00	4,824
DMA0822	12,213	11.64	42.23	30.59	7,633
DMA801	12,248	12.13	54.51	42.38	7,655
DMA802	15,038	11.75	54.91	43.16	9,399
DMA803	6,608	11.32	50.28	38.96	4,130
DMA804	10,269	11.63	50.38	38.75	6,418
DMA805	2,179	9.47	54.68	45.21	1,362
DMA806	25,690	9.50	54.07	44.57	16,056
DMA807	4,323	8.51	55.10	46.59	2,702
DMA808	2,202	10.20	57.65	47.45	1,376
DMA809	8,677	10.50	52.61	42.11	5,423
DMA810A	14,958	10.50	53.67	43.17	9,349
DMA810B	12,648	8.50	45.51	37.01	7,905
DMA811	3,322	12.00	51.38	39.38	2,076
DMA812	38,485	10.00	56.46	46.46	24,053
DMA813	3,160	8.81	49.57	40.76	1,975
DMA1305	20,170	8.50	37.89	29.39	12,606
DMA1306	3,010	6.50	52.45	45.95	1,881
G1-1_1	49,968	9.00	51.89	42.89	31,230
G1-1_2	49,968	9.00	50.81	41.81	31,230
G1-3	48,000	8.60	51.41	42.81	30,000
G2-7	7,680	8.50	44.93	36.43	4,800

Source:JST

3. Wastewater and Sludge Treatment at the Water Treatment Plant

3.1 Overview of the Alternative Options for Wastewater and Sludge Treatment at the Water Treatment Plant

The summary of the alternative options for wastewater and sludge treatment at the water treatment plant is as follows:

- Utilization of the existing drainage system for wastewater and sludge treatment (described in the main report)
- Construction of a resource recovery facility (lagoon) for wastewater and sludge treatment
- Construction of a direct discharge facility to the Mekong River for wastewater and sludge treatment

Following discussions with PPWSA, it was agreed to adopt the option of utilizing the existing drainage system for wastewater and sludge treatment.

The following provides an overview of the examination of these alternative options.

3.2 Resource Recovery Facility (Lagoon)

3.2.1 Basic Concept for Resource Recovery Facility

As an alternative for wastewater and sludge treatment, the basic concept for installing a resource recovery facility (Lagoon) is as follows:

- Although wastewater and sludge-solids (SS) are naturally generated as by-products of the water purification process, a lagoon will be installed as a resource recovery facility to reduce construction and maintenance costs, to comply with environmental regulations, and to promote effective use of water resources and sludge. The lagoon will be used for sedimentation and separation of wastewater from the filter and sedimentation basin, and the supernatant will be discharged from the lagoon outlet to the Bassac River via a storm drainpipe.
- The lagoon can be promoted to relevant government agencies, citizens, and external parties as a resource recovery facility.
- As a resource recovery facility, the closed system will reduce water intake by approximately 2.5 to 3% by returning treated water from the lagoon to receiving wells, leading to savings in electricity costs, chemical expenses, as well as promoting the effective use of sludge as a valuable resource. The sludge can be utilized in landfills, parks, road construction, or green spaces, potentially providing cost recovery and profit opportunities.
- It is considered unlikely that the returned water will have a significant impact on the water treatment process, but to ensure accuracy, further water quality analysis should be conducted. For example, cases have been reported where return water contains higher levels of dissolved substances such as ammonia nitrogen, dissolved manganese, and can influence chlorine injection or manganese circulation during the water treatment process. Therefore, it is necessary to monitor the impact of return water on the treatment process through water quality analysis in the future.

3.2.2 Advantages of the Resource Recovery Facility

The advantages of the resource recovery facility (lagoon) are as follows:

- Although the total amount of solid materials transported off-site remains unchanged, the evaporation effect through sunlight is expected to reduce the moisture content, thereby decreasing the volume of transported sludge and the frequency of transportation. This is expected to improve the efficiency of sludge transportation and reduce transportation costs.
- The lagoon ensures sufficient sedimentation retention time, allowing the supernatant to be discharged directly into the river without any issues.
- By scheduling the construction of the lagoon in the later stages of the construction process, the temporary yard can be utilized effectively during the earlier construction phases.

3.2.3 Resource Recovery Facility Plan

(1) Facility layout plan for Phase 3 Nirodh Water Treatment Plant

The facility layout plan for Phase III of the Nirodh Water Treatment Plant is shown in ***Figure 3-1***.

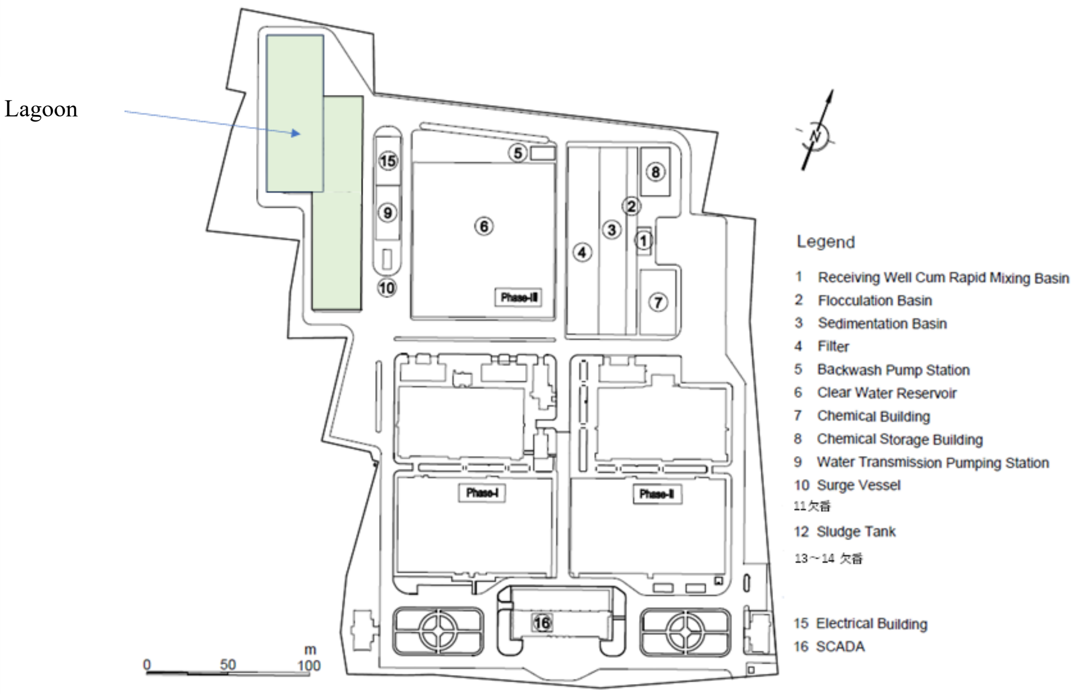


Figure 3-1 Facility Layout of Water Treatment Plant
Source: JST

(2) System Selection for the Resource Recovery Facility

Considering the conditions for selecting the system for the resource recovery facility, including high turbidity, absence of organic matter, and site constraints, a system flow incorporating a lagoon for wastewater treatment, as shown in ***Figure 3-2***, is proposed.

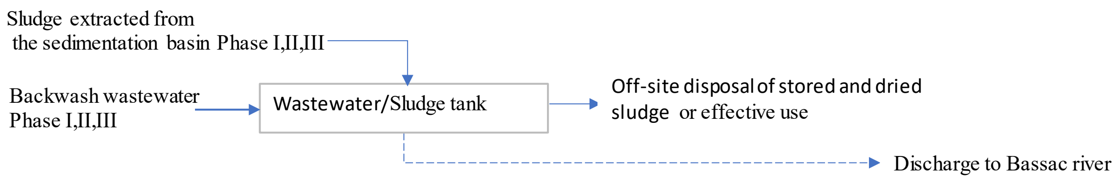


Figure 3-2 Wastewater and Sludge Treatment Process and Flow Diagram
Source: JST

Wastewater and sludge-solids (SS) generated from the water treatment process are inevitable by-products. However, a lagoon will be installed to reduce construction and operation costs, comply with environmental regulations, promote efficient use of water resources, and encourage effective utilization of sludge. In the lagoon, wash water from filtration basins and sludge from sedimentation basins will undergo sedimentation and separation, allowing the supernatant to be discharged into the Bassac River through a stormwater drainage pipe from the lagoon outlet.

(3) Specification of Resource Recovery Facility

1) Conditions for Consideration

- Assessing effluent water quality
- Water source type: River water, Mekong River
- Water treatment system: Rapid filtration system

- Raw water turbidity: High turbidity (5-800 NTU), actual 7-1062 NTU[1]
- Organic matter present: No TOC, mould odour or THMFP
- Wastewater and dewatered sludge disposal methods
- Wastewater treatment effluent: Legal compliance (Cambodian effluent standards) TSS <100 mg/L
- Generated cake moisture content: 80-85 %.
- Water treatment capacity scale and location: Planned water treatment capacity 200,000 m3 /day (Phase III), site constraints.
- Maintenance level: A process/system that can be operated and managed as long as the operator can understand the operation manual without requiring specialized knowledge of wastewater treatment.

2) Design Specification

- Structure or type: Unreinforced concrete, polygonal shape
- Quantity: 2 lagoons
- Type, capacity, dimensions, and volume: Lagoon area of approximately 5,800 m², volume of 20,900 m³, slope gradient (1:1), access ramp for dump trucks (5.5 m wide x 50 m long with a maximum 8% gradient, including a 10 m intermediate platform)
- Ancillary facilities: Inflow, outflow, and overflow pipes; drainage equipment (pipes and valves); loading yard (5.5 m wide in both the long and short directions)

(4) Lagoon System Operation Plan (Draft)

The following operation plan is proposed for a two-lagoon system targeting sludge (inorganic suspended solids) discharged from the water treatment process.

1) Lagoon Scale

- Total volume: 20,900 m³ x 2 lagoons

2) Inflow and Outflow Plan

The inflow and outflow from the water treatment process (including sludge from sedimentation basin withdrawal and filter wash water, excluding rainfall) are estimated as follows:

- Inflow volume: 5,908 m³/day (annual average)
- Inflow SS (suspended solids) volume: 13.6 tons DS/day (annual average)
- Treated water volume≒ equal to inflow volume
- Outflow SS volume: 0.6 tons DS/day (reduced due to sedimentation, based on a river discharge SS concentration of 100 mg/L)

This lagoon system ensures a retention time of approximately 3.54 days, which is considered sufficient for sedimentation and treatment.

3) Operation Cycle

A six-month alternating cycle is planned for the two lagoons:

- Inflow and sedimentation period: approximately 6 months
- Inflow stop and sedimentation period: approximately 1 month
- Drying and dewatering period: approximately 3 months (initial moisture content: 98%, final moisture content: 60%)
- SS removal period: approximately 2 months (780 tons of solids removed over 2 months)

By using the two lagoons alternately, continuous treatment is ensured, and sufficient time is secured for maintenance and solids removal.

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[1] PPWSA data for the 5-year period 2018-2022

Notes:

- Achieving a final moisture content of 60% is considered feasible, but depending on environmental conditions (weather, temperature, and humidity), it may take more than 3 months to reduce from the initial 98%.

4) Frequency of SS Removal

- SS removal is performed from each lagoon once every 6 months.

Key Points to Consider:

- The inflow of inorganic solids is 13 t-DS/day. Therefore, the accumulation over 6 months is calculated as follows:
  13 t-DS × 180 days = 2,340 t-DS.
- Considering the lagoon's total capacity of 20,900 m³, it is necessary to evaluate how much of this capacity is occupied by accumulated inorganic solids. Assuming a density of 1,500 kg/m³, the maximum amount of solids that can be retained in the lagoon is:
  20,900 m³ × 1,500 kg/m³ = 31,350,000 kg = 31,350 t-DS.
- Accumulating 2,340 t-DS over 6 months occupies a relatively small percentage of the total lagoon capacity. However, in practice, sedimentation and other factors may affect treatment efficiency.
- Excessive accumulation of solids may lead to deterioration in water quality and reduced treatment efficiency in the lagoon. High concentrations of organic matter and nutrients can also cause algae growth and odor issues.
- Therefore, the 6-month SS removal cycle should be re-evaluated based on actual accumulation and water quality conditions. More frequent removal (e.g., every 3 months) may be necessary in the following cases:
  - Faster-than-expected accumulation or unfavorable environmental conditions (e.g., temperature, humidity) may require earlier removal to maintain operational efficiency.
  - Regular monitoring of actual solids accumulation is essential for flexible adjustments to the removal schedule.
- For SS removal every 6 months, approximately 1,170 t (half of 2,340 t) needs to be removed each time. Assuming the use of 10-ton dump trucks or watertight container vehicles, removing solids six times a day would require about 20 vehicles.

5) Final Disposal

- Disposal by landfill or reuse for land development.

(5) Estimated Construction and Maintenance Costs

Table 3-1 Estimated Construction and Maintenance Costs

Items	Estimated Cost
Facility Construction Cost (Civil and Building Works)	126 million JPY
Facility Construction Cost (Mechanical and Electrical Equipment)	49 million JPY
Total Facility Construction Cost	175 million JPY
Maintenance Cost (Electricity)	11 million KHR/year
Maintenance Cost (Repairs)	9 million KHR/year
Maintenance Cost (Sludge Disposal)	1,242 million KHR/year

Source: JST

3.3 Direct Discharge Facility to the Mekong River

As an alternative plan for wastewater and sludge treatment, the following cases are considered for installing a direct discharge facility to the Mekong River:

- Discharge by gravity flow
- Discharge by pump pressure

3.3.1 Discharge by Gravity Flow

(1) Facility Overview

The potential discharge point for gravity flow is approximately 1.8 km away. However, this discharge point is upstream of the Nirodh Water Treatment Plant's intake location. Additionally, since the discharge point is a tributary of the Mekong River with a relatively small water volume, the dilution rate after discharge would be significantly low. Therefore, this location is considered unsuitable for discharge.

Figure 3-3 Route of Gravity Flow Discharge Pipeline and Condition of Potential Discharge Point

(2) Specification of the Facility

- Estimated average annual discharge and sludge volume for Nirodh Phase III: 1,356 m³/day
- Gravity flow system
- Nirodh Water Treatment Plant discharge balancing pond low water level: +4.4 m
- Mekong River water levels (2000–2017):
- Maximum high water level: +10.15 m AMSL Minimum low water level: +0.55 m AMSL
- Discharge pipe: Ductile iron pipe, diameter 300 mm
- Distance from Nirodh Water Treatment Plant to Mekong River discharge point: approx. 1.8 km
- River protection structure: 10 m × 10 m

3.3.2 Discharge by Pumping System

(1) Facility Location

The distance from the existing water treatment plant to the potential discharge point downstream of Noria Island is approximately 6.1 km. The discharge point is expected to be on public land managed by the National Committee for Disaster Management.

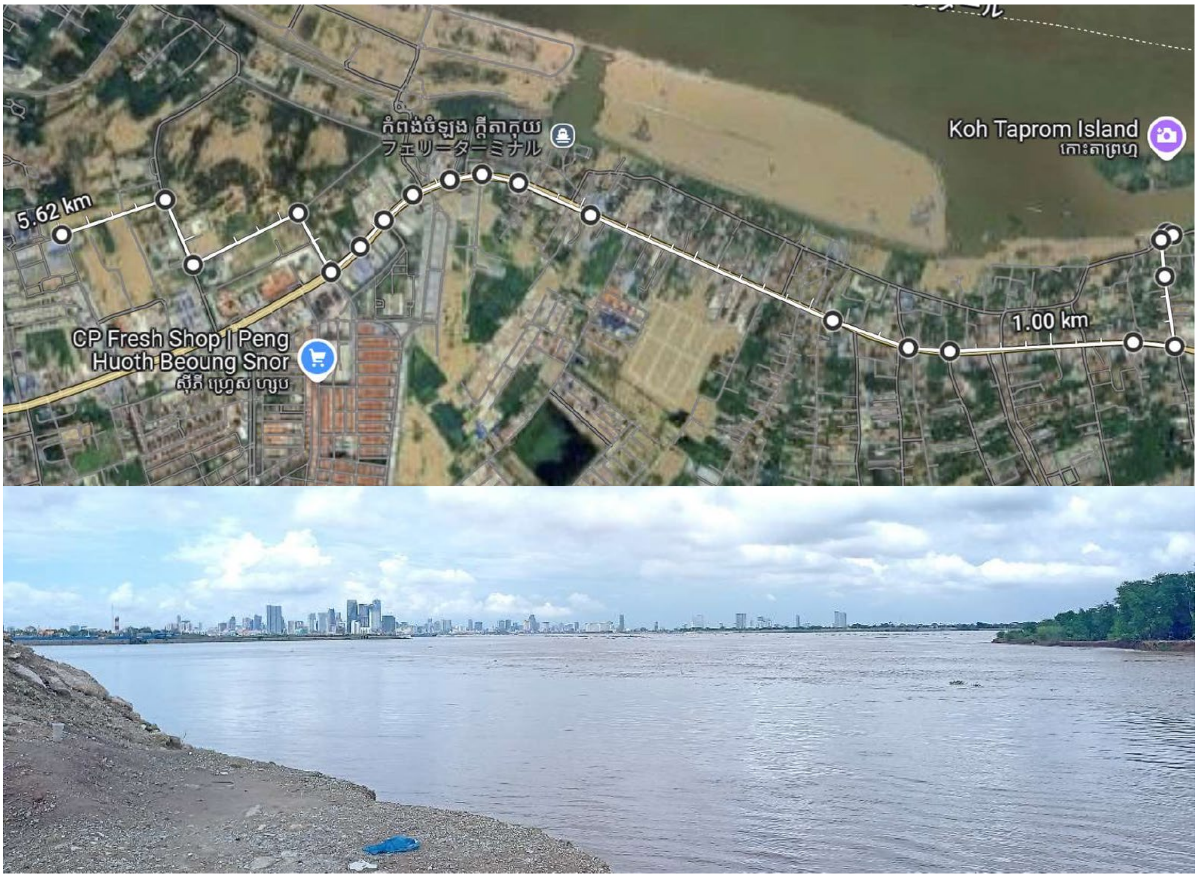


Figure 3-4 Route and Condition of the Discharge Pipeline for Pumped Discharge System

Source:JST

(2) Specification of the Facility

- Annual average discharge and sludge volume from Nirodh Phase III is estimated at 1,356 m³/day.
- Pumped discharge system.
- Nirodh Water Treatment Plant discharge balancing pond low water level: +4.4 m AMSL.
- Mekong River water levels (2000–2017):
- Maximum high water level: +10.15 m AMSL Minimum low water level: +0.55 m AMSL
- Discharge Pipeline:
- Ductile iron pipe with a diameter of 300 mm.
- Distance from Nirodh Water Treatment Plant to the Mekong River discharge point : Approx. 5.6 km
- River Protection : 10 m × 10 m

(3) Estimated Construction and Maintenance Costs

Table 3-2 Estimated Construction and Maintenance Costs

Discharge by Gravity Flow		Discharge by pumping System	
Construction cost of adjustment pond and sludge pond	5,930,000JPY	Construction cost of adjustment pond and sludge pond	5,930,000JPY
		Pump station construction cost	21,330,000JPY
Drainage pipe construction cost:	34,200,000JPY	Drainage pipe construction cost	106,400,000JPY
Construction cost of discharge point facilities	5,550,000JPY	Construction cost of discharge point facilities:	5,550,000JPY
Total construction cost:	45,680,000JPY	Total construction cost:	139,210,000JPY
		Maintenance cost (pump operation cost)	5,328,000JPY

Source: JST

The key points to note are as follows:

- An Environmental Impact Assessment (EIA) must be conducted, and approvals from relevant authorities (MOE, CNMC) as well as EMP approval must be obtained.
- As the drainage pipes will be installed along private roads, the necessary permits and agreements must be secured.
- The proposed drainage point, being a tributary of the Mekong River, has insufficient water flow and is therefore unsuitable as a discharge outlet. Alternative locations should be considered, taking hydraulic conditions into account.
- Pumped drainage will incur ongoing operation and maintenance costs.

4. Outline Design of the Facility

Table 4-1 presents the design specifications for the intake and raw water transmission main for the adopted alternative. The design specifications for the water treatment facilities are shown in ***Table 4-2***, and the design specifications for the distribution monitoring facilities are also provided in ***Table 4-3***.

Table 4-1 Outline Design Specifications for Raw Water Intake and Raw Water Transmission main

Facility	Structure/Type	Capacity, dimensions, and volume	Quantity
Intake pump	Submersible pump	3,650 m^3/hr (60.8 m^3/min) x 32m x 440 kW	1 Unit
Raw water transmission main	Ductile iron pipes	Diameter 1400 mm	Approx. 1.64 km

Source: JST

Table 4-2 Outline design Specifications for Water Treatment Facilities

Facility	Structure/Type	Capacity, dimensions, and volume	Quantity
Receiving well	Reinforced concrete, rectangular	internal L16.8 m x W 1.4 m x D 1.15 m	1 Unit
Raw water flow meter chamber	Reinforced concrete, rectangular	external L4.0 m x W 5.0 m x D 4.5 m	1 Chamber
Mixing basin	Reinforced concrete, rectangular, Type of mixing: mechanical mixing system.	internal L2.5 m x W 2.5 m x D 5.04 m	6 Units
Flocculation basin	Reinforced concrete, rectangular, Type of mixing: mechanical mixing system.	internal L6.1 m x W 6.1 m x D 4.36 m	18 Units
Sedimentation basin	Reinforced concrete, Method of sedimentation: upward-flowing inclined tube	internal L12.5 m x W 6.1 m x D 4.44 m	18 Units
Filter	reinforced concrete, Filtration method: constant speed filtration, single-layer filtration; cleaning method: back-flow cleaning + air cleaning method.	internal L13.14 m x W4.9 m x D3.08 m	18 Units
Clear water reservoir	Reinforced concrete, rectangular	internal L86.6 m x W 46.77 m x D 4.54 m	2 Units
PAC & LIME Feeding System	PAC Solution Tank: reinforced concrete Injector	35 m^3 (4 m x 3.8 m x 2.3 m) Diaphragm pump	2 tanks 3 units
	LIME Solution Tank: reinforced concrete Injector	35 m^3 (4 m x 3.8 m x 2.3 m) Diaphragm pump	2 tanks 3 units
Chlorination facility	On-site Hypochlorite System, Hypochlorite Injector、Ancillary facilities		whole set

Facility	Structure/Type	Capacity, dimensions, and volume	Quantity
Electrical and instrumentation equipment	Equipment for receiving, transforming, distributing and powering electricity, monitoring and control systems (SCADA), equipment for measuring flow, water levels and water quality, etc.		whole set
Transmission pumping station	Horizontal Double Suction Volute Pump, VFD control + On/Off Control System Surge Vessel	3,330 m^3（55.6 m^3/min）×53 m×700 kW 50 m^3	6 Units (incl. 2 Stand-by) 2 units
Water Quality Testing Equipment	Replacement of Distillation Production Equipment Jar Tester, Digital Microscope		One unit
Other facilities	In-plant raw water transmission, wastewater and sludge drains, in-plant treated water transmission, water supply service pipes, walkways, plantings, car parks, etc.		whole set

Source: JST

Table 4-3 Outline Design of distribution monitoring facility

Facility	Structure/Type	Capacity, dimensions, and volume	Quantity
DMA Monitoring (Entrance)	Flowmeter, ductile iron pipe	Diameter 250 mm、PN10	4 set
	Flowmeter, ductile iron pipe	Diameter 300 mm、PN10	6 set
	Flow meter room, saddle faucet, water quality meters (7 items: residual chlorine, turbidity, color, water pressure, pH value, water temperature, electrical conductivity), external display communication device, etc.		10 set

The preliminary design specifications for the water transmission and distribution facilities are shown in ***Table 4-4***. These specifications are based on the alternative route.

Table 4-4 Outline Design Specifications for Transmission and Distribution Facilities

Facility	Structure/Type	Capacity, dimensions, and volume	Quantity
Transmission Pipe	Ductile Iron Pipe	Diameter 600 mm、PN10	1.8km
	Ductile Iron Pipe	Diameter 800 mm、PN10	1.3km
	Ductile Iron Pipe	Diameter 1,000 mm、PN10	2.4km
	Ductile Iron Pipe	Diameter 1,200 mm、PN10	1.1km
	Ductile Iron Pipe	Diameter 1,400 mm、PN10	5.0km
	Ductile Iron Pipe	Diameter 1,600 mm、PN10	5.1km
	Ductile Iron Pipe	Diameter 1,800 mm、PN10	3.0km
	Ductile Iron Pipe	Diameter 2,000 mm、PN10	13.5km
	Coated Steel Pipe for Water Service (For Pipe Jacking)	Diameter 2,000 mm、PN10	1,250m
No.1 River Crossing	Pipe Jacking	Diameter：2,400 mm Method：Slurry Method Main Pipe for Jacking System: Concrete Jacking Pipe	620 m
	Maintenance Manhole	Driving Shaft Inner Diameter：10.0 m (Outer Diameter：14.0 m) Shaft Depth: 26.0 m Method：Press in Cassion Method Occupation Area ：720 m^2	1 unit
		Reception Shaft Inner Diameter：6.0 m (Outer Diameter：7.0 m) Shaft Depth: 26.0 m Method：Press in Cassion Method Occupation Area ：500 m^2	1 unit

Facility	Structure/Type	Capacity, dimensions, and volume	Quantity
No.2 River Crossing	Ductile Iron Pipe	Diameter: 2,000 mm、PN10 Route Number: R200-1 Method：Transmission Pipe Bridge	44 m
No.3 River Crossing	Pipe Jacking	Diameter：2,400 mm Method：Slurry Method Main Pipe for Jacking System: Concrete Jacking Pipe	630 m
	Maintenance Manhole	Driving Shaft Inner Diameter：10.0 m (Outer Diameter：14.0 m) Shaft Depth: 26.0 m Method：Press in Cassion Method Occupation Area ：720 m^2	1 unit
		Reception Shaft Inner Diameter：6.0 m (Outer Diameter：7.0 m) Shaft Depth: 26.0 m Method：Press in Cassion Method Occupation Area ：500 m^2	1 unit
No.4 River Crossing Near PrekHo Bridge	Ductile Iron Pipe	Diameter: 1,600 mm、PN10 River: (Canal) Route Number: R160-1 Method：Transmission Pipe Bridge	100m
Distribution Pipe "Improvement"	High Density Polyethylene Pipe	Diameter 90 mm、PN10	6 m
	High Density Polyethylene Pipe	Diameter 110 mm、PN10	4,069 m
	High Density Polyethylene Pipe	Diameter 160 mm、PN10	15,476 m
	High Density Polyethylene Pipe	Diameter 225 mm、PN10	19,805 m
	Ductile Iron Pipe	Diameter 250 mm、PN10	5,485 m
	Ductile Iron Pipe	Diameter 300 mm、PN10	23,520 m
	Ductile Iron Pipe	Diameter 350 mm、PN10	623 m
	Ductile Iron Pipe	Diameter 400 mm、PN10	262 m
	Ductile Iron Pipe	Diameter 500 mm、PN10	251 m
	Ductile Iron Pipe	Diameter 600 mm、PN10	4 m
Distribution Pipe "Development"	High Density Polyethylene Pipe	Diameter 63 mm、PN10	237,772 m
	High Density Polyethylene Pipe	Diameter 90 mm、PN10	236,542 m
	High Density Polyethylene Pipe	Diameter 110 mm、PN10	415,746 m
	High Density Polyethylene Pipe	Diameter 160 mm、PN10	158,422 m
	High Density Polyethylene Pipe	Diameter 225 mm、PN10	67,389 m
	Ductile Iron Pipe	Diameter 250 mm、PN10	54,118 m
	Ductile Iron Pipe	Diameter 300 mm、PN10	80,967 m

Source: JST

ANNEX 8 CAPACITY CALCULATION FOR NIRODH WATER TREATMENT PLANT

Phnom Penh/Cambodia
Capacity Calculation for Nirodh Water Treatment Plant

Item		Description			
Planned Flow		Q=	200 MLD		
		=	200,000 cu m/day		
	Criteria	Reserve Capacity		R 1=	5 %
					%
Plant Capacity (Daily Max)		Q=	210,000 cu m/day		
		=	8,750 cu m/hour		
		=	145.8 cu m/min		
		=	2.431 cu m/sec		
(1) Pre-Sedimentation Basin					
	Type	Rectangular, Horizontal Flow ------N/A			
(2) Receving/Dividing Well					
	Criteria	Retention Time		T =	1.5 min
		Recirculation		a =	0.0 %
	Dimension	Rectangular		1 units	
		L m x	W m x	D m x	units
		16.8	1.4	1.15	1
		V=	27.0 cu m		
		T=	0.19 min		
(3) Rapid Mixing Chamber					
	Criteria	Retention Time	T=		1 - 5 min
		Recirculation	a =		0.0 %
	Dimension	Rectangular (3tanks x 2trains)			6 units
		L m x	W m x	D m x	units
		2.5	2.5	5.04	6
	Unit Volume	UV =	31.5 cu m/unit		
	Total Volume	V =	189 cu m		
	Retention Time	t =	1.3 min		
	Mixing	Mechanical Mixing			
(4) Flocculation Basin					
	Criteria	Retention Time		T =	20 - 40 min
		Recirculation		a =	0 %
		Required Volume		V =	2,917 cu.m to
					5,833 cu.m
		Rectangular (9tanks x 2trains)			
	Dimension		18 units		
	Unit Flow	q =	8.1 cu m/min/basin		
		W m x	L m x	D m	x No.of Channel
		6.1	6.1	4.36	1
	Unit Volume	UV =	162.2		
	Total Volume	V =	2,919 cu m		
	Retention Time		20.0 minutes		

Item	Description				
(5) Sedimentation Basin					
Type	Rectangular, Horizontal Flow + Inclined Tube Up-Flow				
Criteria	Retention Time		T =	1.5 hours	
	Hor. Flow Velocity		v <	0.40 m/min	
	Depth		D =	3 - 4 m	
	Depth of 30 cm or more is provided for sludge settlement.				
	Surface Load at Tube Settler		a =	80 mm/min	
	Surface Load of Tube		a =	7 - 14 mm/min	
Dimension	Rectangular (9 tanks x 2trains)				
	No.	18 basins			
	W m	x L m	x D m	x N	
Up-Flow	6.1	12.5	4.44	18	
Height of Tube	H =	0.91 m 0.5-1.5			
Clearance of Tube	C =	52.24 mm			
Valid Area of Tube	VA=	17.4 sq m/sq m			
Volume	VU =	339 cu m/basin			
	Total =	6,094 cu m			
Retention Time	T =	0.7 hours	=	41.8 min	
	v =	0.113 m/min < 0.7	at enterence of tube settler		
Up-Flow Velocity	v =	31.9 mm/min < 80	at Tube Settler		
Surface Load of Tube	a =	1.8 mm/min 7 - 14			
Sludge Removal	Sludge Hopper with De-sludge Piping				

Sludge Amount / Solid Amount (ton-DS)

So = Q * (K*(T1-T2)+B*C*156/102)*10^-6

where So:Sludge dry weight(ton)

- Q :Treated water amount(m3/d)
- K :Coefficient converting turbidity to SS (0.8-1.5 ->>1.0) 1.000
- T1 :Turbidity in raw water (ave= 150 (after approx. 12 hrs pre-sedimentation of 500 NTU rainy season raw water)
- T2 :Turbidity after Sedimentation (ave = 5)
- B :Alum dosage rate (ave.= 12
- C :Concentration of AL2O3 29%

So = 31.57 ton-DS/day

Water Contents of Drained Sludge (with wash-out water)

w = 99.0 %

Frequency of Cleaning : Continuous

Sludge Volume	Total	v =	3,157 cu.m/day
		So =	31.57 ton-DS/day
SS Contents	s =	9,900 mg/l	

(6) Rapid Sand Filter

Type Down Flow, Single Media

Item	Description		
No.	1 trains x		
	18 units (wash		2 units)
Unit Flow	q = 11,667 cu m/day/unit		
Criteria	Filtration Rate	Fr =	180 - 240 m/day
		=	5.0 - 6.25 m/hour
	Filter Area per Unit	A <	150 sq m
Dimension	W m x L m x N units		
	4.9 13.14 18 (18 filters/group)		
	(2.45*2)		
	A = 64.4 sq m/unit		
Filtration Rate	Fr = 181.2 m/day		
Filtration Rate	Fr'= 191.9 m/day		
during washing	1 unit out of 18 units is washing		
	Fr'= 203.8 m/day		
	1 unit out of 18 units is under maintenance, 1 unit is washing		
Filter Washing			
Frequency	Once a day for each filter		
Rate	Air Scouring	air rate =	1.00 m3/m2/min
		duration =	4 min
	Air + Rinsing	water rate =	0.20 m3/m2/min
		duration =	4 min
	Rinsing	rate =	0.40 m3/m2/min
		duration =	8 min
Water Amount	Air + Rinsing	Vs =	51.5 cu m/unit
for washing	Backwashing	Vb =	206.0 cu m/unit
		Vs + Vb =	257.5 cu m/unit
for Total Units	Total Amount for Washing		4,635.8 cu m/day
	Percentage for Planned Flow		2.2 %
Solid Amount	So = Q*K*(T1-T2)*10^-6		
in Wastewater	where So:Sludge dry weight(ton)		
(ton-DS)	Q :Treated water amount(m3/d)		
	K :Coefficient converting turbidity		
	to SS (0.8-1.5 ->>1.2)		1.000
	T1 :Turbidity before filter(ave=		5
	T2 :Turbidity after filter(ave =		0
	So = 1.05 ton-DS/day		
SS Contents	s = 226 mg/l		
(7) Clear Water Reservoir			
Criteria	Retention Time	T >	4.0 hours
Required Volume	V = 0 cu m		

Item	Description				
Dimension	No.	2 units			
	L m	x W m	x D m	m x N	units
	86.6	46.77	4.54		2
Total Volume	V =	36,781 cu m			
Retention Time	T =	4.41 hours			

(8) Backwash Wastewater Tank

Backwash Water Amount	v =	4,636 cu.m/day			
Criteria	Cycle (wash+discharge)		2.0 hour/cycle		
Wash	Washing (1 wash/day)		18 wash/day		for total
	Washing (wash/cycle)		2 wash/2 hour		
Tank	Starage	1 tank,	Settling	1 tank	
Required Volume	V =	386 cu m			
Dimension	L m	x W	m x D m	x units	
	12.00	12.0	3.5	2	
	Rectangular		504 cu.m/tank		
Total Volume	v =	1,008 cu m			

(9) Resource recovery facility (Lagoon)

Criteria	Retention Time		T >	1.5 days of the total drainage volume of filtration basin washing effluent and sedimentation basin drainage water
Dimension	No.	2 units		
Total Area		5,800 sq m		
□ Effective water depth		4.0 m		
Total Volume	V =	20,900 cu m		

ANNEX 9 RESULT OF HYDRAULIC ANALYSIS

1. Condition of Hydraulic Analysis

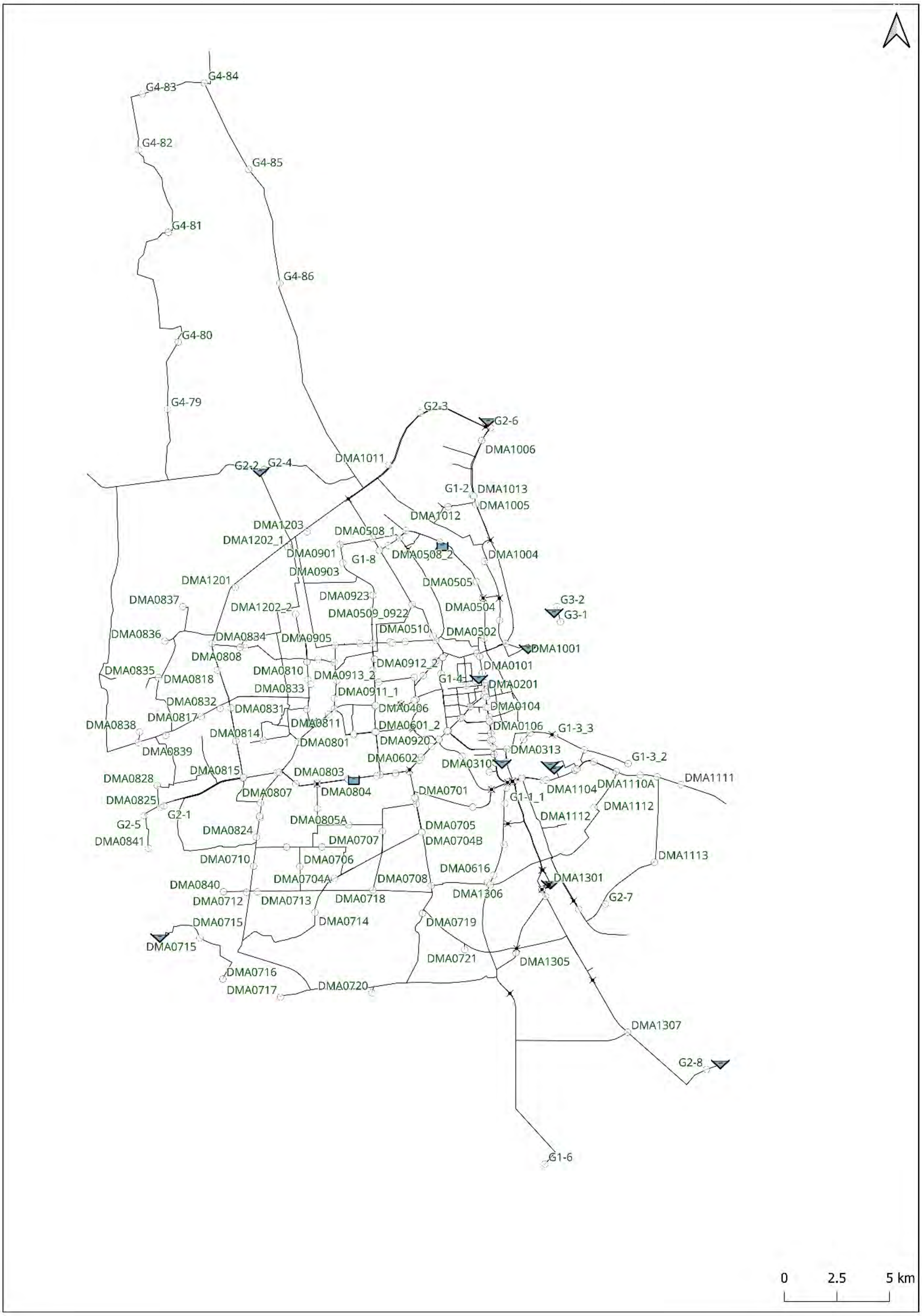
The pipeline calculation conditions were shown below.

Item	Contents
Water Supply Area	Greater Phnom Penh, and Large-Scale City Development (including a part of Kandal Province)
Water Demand	Total : 1,814,000 m^3/day (The Projection Maximum Water Supply Demand in 2030) Nirodh Water Supply Expansion Project Phase 3 : 463,267 m^3/day (The Projection Maximum Water Supply Demand in 2030)
Peak Factor	1.60
Requirement Pressure	Above 3.0 bar at edge of the Transmission Network
DMA	Total: 184, and 19 Large Scale City Development Area Nirodh Water Supply Expansion Project Phase 3 : 51DMA
Hydraulic Calculation Software	WaterGEMS
Formula	Hazen Williams
Flow Velocity Factor (C)	Pipe after install over 20 years : 110 Pipe after install less than 20 years: 130
Water Treatment Capacity	200,000 m^3/day
Actual Transmission Pump Head	60.92m (Same as Actual Transmission Pump Head of Nirodh Phase I.II)
Pipe Material	According to PPWSA Standard Ductile Iron Pipe: Nominal Diameter over 250mm High Density Polyethylene Pipe: Nominal Diameter Less Than 250mm

Source: JST

2. Network Model

The network model and analysis results are shown below.



3. Result of Hydraulic Analysis

The results of hydraulic analysis are shown below.

Results of Hydraulic Analysis (Junction)

Label	DMA	Elevation (m)	Demand (m³/day)	Hydraulic Grade (m)	Pressure (m)
J-3011	G1-6	7.40	23,100	17.75	8.24
J-2637	DMA0606	10.47	7,845	47.06	27.78
J21544	DMA0604	10.71	10,213	47.80	28.35
J63082	DMA0602	10.80	9,590	48.06	28.90
J-3105	DMA0841	15.60	8,573	57.20	29.12
J-3039	G2-5	16.00	34,558	57.38	29.15
J-1674	DMA0603	11.14	16,827	48.41	29.38
J-1594	DMA1305	8.50	20,170	51.67	29.39
J-3060	DMA0721	8.74	26,146	51.87	29.61
J-3164	DMA0824	13.10	16,758	54.73	29.62
J-990	DMA0605	11.35	15,747	48.60	29.64
J-1137	DMA0410	11.39	8,882	48.69	29.80
J-3156	DMA0826	13.00	17,757	54.94	29.81
J-3159	DMA0823	13.10	4,069	55.03	29.83
J-3140	DMA0825	15.00	13,840	57.25	29.88
J-1730	DMA0308	11.43	17,778	48.72	29.92
J-3034	G2-1	15.80	8,480	57.60	29.92
J-2981	G1-7	10.89	18,683	54.46	29.98
J-1646	DMA0806-2	11.65	7,718	54.36	30.00
J-2976	DMA0804	11.50	29,944	54.36	30.14
J21852	DMA0710	13.80	2,966	54.98	30.22
J-412	DMA0807	12.78	6,592	55.07	30.28
J-1515	DMA0409	11.38	10,851	48.90	30.31
J-2338	DMA0913_2	10.50	6,008	51.40	30.36
J-3055	DMA0822	11.64	12,213	54.37	30.59
J-320	DMA0918	10.63	7,302	54.28	30.69
J-1386	DMA0507_1	8.50	6,715	56.04	30.71
J-1395	DMA0913_1	10.62	6,008	50.77	30.72
J-423	DMA0920	10.61	26,653	54.28	30.73
J-2930	DMA0711	12.00	3,878	54.54	30.73
J-3138	DMA0828	15.50	11,437	57.91	30.78
J-3082	DMA0838	16.00	14,498	58.43	30.79
J-1088	DMA0407	11.43	12,595	49.15	30.85
J-1808	DMA0803	10.79	20,326	54.33	30.86
J-854	DMA0819	13.69	8,680	56.15	30.88
J21569	DMA0709	10.80	40,712	54.02	30.90
J57127	DMA0706	12.33	21,934	54.60	30.93
J-586	DMA0406	10.10	19,746	50.18	30.97
J-2204	DMA0821	13.58	5,723	56.11	30.98
J-491	DMA0917	12.13	6,854	55.37	30.99
J-3183	DMA0835	14.69	9,613	58.07	31.06
J-1523	DMA0601_1	10.50	20,309	54.31	31.16

Label	DMA	Elevation (m)	Demand (m^3/day)	Hydraulic Grade (m)	Pressure (m)
J-2961	DMA0915	12.50	5,816	55.54	31.17
J-1281	DMA0508_1	8.50	3,866	56.27	31.26
J-1391	DMA0802	10.75	11,853	54.66	31.42
J-2795	DMA0912_1	12.11	4,746	55.58	31.45
J-1059	DMA0405	11.37	14,363	49.42	31.49
J-707	DMA0404	11.82	18,083	51.07	31.53
J-984	DMA0805B	10.50	22,451	54.46	31.57
J-2050	DMA0811	12.42	10,138	55.77	31.57
J-507	DMA0902	7.65	30,288	56.08	31.58
J-44(2)	DMA0840	14.47	16,144	55.46	31.61
J-527	DMA0505	8.50	29,805	56.76	31.70
J-2909	DMA0805A	10.50	22,451	54.30	31.73
J-327	DMA0408	10.10	13,970	50.56	31.87
J22308	DMA0714	12.80	6,082	54.81	31.91
J-2979	DMA0801	10.80	13,853	54.90	31.94
J-1363	DMA0609-1	8.92	4,510	47.79	32.06
J-3174	DMA0827	12.00	4,856	55.86	32.11
J-431	DMA0806-1	10.76	7,718	54.86	32.15
J-729	DMA0508_2	7.79	3,866	56.36	32.15
J-1221	DMA0601_2	10.53	20,309	54.86	32.23
J-3041	DMA0717	9.00	2,606	53.29	32.41
J-3184	DMA0916	10.00	6,198	50.76	32.45
J-1723	DMA0919	10.10	3,890	50.81	32.47
J-1101	DMA0820	14.50	10,414	57.79	32.49
J-59	DMA0403	11.11	5,858	51.23	32.51
J-3037	DMA0839	16.00	9,290	59.15	32.51
J-2849	DMA0719	9.95	9,531	53.65	32.53
J-977	DMA0607	10.50	12,091	54.83	32.56
J-874	DMA0814	13.02	19,842	58.04	32.85
J-3063	DMA0720	9.00	2,528	53.45	32.92
J-1370	DMA0402	11.17	7,376	51.41	32.95
J-1175	DMA0815	14.50	12,770	58.01	32.97
J-974	DMA0307	11.34	19,704	50.02	32.98
J22321	DMA0608	10.50	35,230	54.95	33.17
J-2997	DMA0812	12.14	26,190	57.46	33.21
J-3168	DMA0911_1	11.00	9,323	55.93	33.31
J-3178	DMA0713	13.00	3,118	55.56	33.33
J-3176	DMA0712	12.70	2,258	55.51	33.49
J21564	DMA0707	10.50	10,061	54.94	33.79
J-3166	DMA0911_2	11.00	9,323	56.19	33.85
J-939	DMA0401	11.06	6,576	51.74	33.89
J-3033	DMA0829	15.79	11,269	59.62	33.89
J-1628	DMA0503	11.03	19,616	51.80	34.07

Label	DMA	Elevation (m)	Demand (m^3/day)	Hydraulic Grade (m)	Pressure (m)
J-1678	DMA0704B	10.50	13,210	55.00	34.09
J-374	DMA0705	10.50	17,798	55.02	34.14
J-1251	DMA0309	9.26	16,699	48.63	34.17
J-3126	G4-81	12.91	2,170	60.38	34.18
J-64927	DMA0716	13.00	3,187	51.82	34.19
J-161	DMA0302	9.92	17,618	49.33	34.21
J57121	DMA0715	16.00	4,256	53.11	34.29
J-101	DMA0305	9.57	6,701	49.00	34.33
J-1433	DMA0106	9.85	20,614	49.61	34.58
J-1731	DMA0908	10.50	9,918	53.50	34.59
J-1048	DMA0703	10.50	24,142	55.31	34.64
J-3003	DMA0704A	10.76	13,210	55.23	34.67
J-2717	DMA0921	10.52	5,533	53.73	34.77
J-1421	DMA0304	9.66	13,219	49.30	34.81
J-2336	DMA1005	8.50	29,894	59.22	34.83
J-1894	DMA0906	10.77	5,365	54.43	34.85
J-3195	DMA0506	6.00	29,674	56.94	34.86
J21557	DMA0702	10.50	1,102	55.45	34.95
J-1825	DMA0310	9.36	9,762	48.94	35.05
J-715	DMA0301	9.32	20,205	49.05	35.05
J-2112	DMA0701	10.50	7,838	55.49	35.06
J-1543	DMA0205	10.71	12,816	50.67	35.06
J-1353	DMA0923	10.23	5,189	53.94	35.09
J-3070	DMA0311	9.95	15,586	49.24	35.24
J-23	DMA0303	9.51	5,317	49.40	35.37
J-1844	DMA0609-2	10.20	4,510	49.44	35.48
J-1275	DMA0306	9.34	8,026	49.36	35.50
J-2235	DMA0910	10.50	6,658	56.67	35.54
J57112	G1-3_2	8.60	12,000	54.00	35.59
J-1036	DMA0914	10.17	3,898	52.31	35.64
J-31	DMA0833	10.55	13,752	57.77	35.64
J-1546	DMA0905	11.35	13,653	56.66	35.65
J-493	DMA0204	9.92	10,910	50.02	35.66
J-813	DMA0907	9.52	7,502	52.72	35.68
J-2185	DMA0203	9.86	8,744	50.38	35.70
J-856	DMA0202	9.96	12,766	50.68	35.79
J-3142	DMA0816	13.50	10,424	58.99	35.81
J-2993	G1-5	10.55	4,163	57.85	35.83
J-304	DMA0809	10.88	11,731	57.52	36.06
J-3179	DMA1004	8.50	9,763	59.31	36.20
J-219	DMA0909_1	9.04	4,152	52.68	36.25
J-1025	DMA0312-1	9.34	7,605	49.42	36.28
J-3000	DMA0817	14.51	26,232	60.17	36.33

Label	DMA	Elevation (m)	Demand (m³/day)	Hydraulic Grade (m)	Pressure (m)
J-697	DMA0105	9.79	17,274	50.58	36.38
J-3050	G2-7	8.50	7,680	54.33	36.43
J-600	DMA0313	8.92	11,797	49.10	36.87
J-448	DMA0314	8.77	4,755	48.80	36.93
J-3121	G4-80	13.02	1,904	61.55	37.01
J-2612	DMA1110B	8.50	12,648	54.69	37.01
J-2618	DMA0808	12.50	20,072	59.27	37.17
J54275	DMA1307	8.00	13,544	47.46	37.36
J-3116	G4-83	8.00	1,877	59.75	37.40
J-3115	G4-82	8.00	1,608	59.75	37.42
J-3172	DMA0912_2	10.00	4,746	57.98	37.46
J57120	DMA0715	16.00	0	54.52	37.65
J-1695	DMA0903	10.22	7,571	57.42	37.68
J-73	DMA0810	11.26	6,029	58.89	37.73
J-1665	DMA0502	10.50	9,554	52.25	37.74
J-2568	DMA0510	8.19	10,194	52.90	37.92
J-1889	DMA0831	13.51	3,376	60.12	37.99
J-1567	DMA0830	12.53	17,253	59.87	38.12
J-3170	DMA0909_2	10.00	4,152	58.38	38.14
J22319	DMA0718	10.50	5,184	56.38	38.20
J-334	DMA0904	7.25	12,253	52.44	38.26
J-3043	DMA0832	13.70	8,090	60.68	38.27
J-1144	DMA0104	9.85	17,659	51.65	38.29
J-3103	G4-84	8.00	1,774	60.19	38.33
J-3120	G4-79	13.98	2,054	62.60	38.65
J31288	DMA1104	11.63	10,269	56.74	38.75
J-3015	DMA0813	12.50	14,656	60.23	38.77
J-1805	DMA0504	8.98	7,816	51.98	38.82
J-1576	DMA0501	10.50	18,224	52.66	38.92
J31287	DMA1103	11.32	6,608	56.70	38.96
J-1061	DMA0201	10.01	3,658	52.19	39.16
J5585	DMA1111	12.00	3,322	57.03	39.38
J-2233	DMA0103	10.38	16,733	52.53	39.43
J-2647	DMA1012	8.50	1,936	61.22	39.47
J-2518	DMA0101	10.50	20,896	52.81	39.53
J-1612	G1-4	10.77	11,942	52.50	39.57
J-688	DMA0901	10.50	1,923	59.10	39.59
J-2575	DMA0102	10.50	4,555	52.76	39.71
J-2787	DMA0315	8.89	5,822	50.02	39.78
J-2819	DMA1202_2	11.67	2,003	60.07	39.84
J-2866	DMA0836	12.50	5,739	61.05	40.16
J-3135	DMA0818	12.50	13,784	60.91	40.31
J57113	G1-3_3	8.60	12,000	56.01	40.40

Label	DMA	Elevation (m)	Demand (m^3/day)	Hydraulic Grade (m)	Pressure (m)
J-3048	DMA1113	8.81	3,160	56.27	40.76
J21550	DMA1302	10.50	18,288	52.31	40.85
J-466	DMA0312-2	8.86	7,605	50.42	40.88
J-918	DMA1304	10.50	10,174	52.35	40.94
J21549	DMA1303	10.41	18,846	52.38	41.11
J-1734	DMA0834	13.36	6,835	61.78	41.27
J-3111	DMA0837	10.50	6,890	60.76	41.45
J-804	DMA0610	8.25	22,874	57.03	41.76
J-3203	G1-1_2	9.00	49,968	57.00	41.81
J64893	DMA0613	8.26	11,904	57.06	41.83
J-42(1)	DMA0107	10.50	4,117	53.33	41.88
J14104	G1-3_1	8.60	24,000	56.66	41.95
J21560	DMA0708	9.10	5,272	57.21	41.97
J-2824	DMA1109	10.50	8,677	57.54	42.11
J-1278	DMA1101	12.13	12,248	58.48	42.38
J16757	DMA1003	8.50	15,184	53.34	42.41
J-3204	G1-1_1	9.00	49,968	57.48	42.89
J31283	DMA1102	11.75	15,038	58.64	43.16
J63086	DMA1110A	10.50	14,958	57.99	43.17
J-2826	DMA0509_0922	7.96	28,829	60.21	43.23
J-144	DMA1002	8.76	14,013	53.88	43.34
J-211	DMA1301	9.42	6,824	52.96	43.48
J-3206	DMA0615	8.00	10,234	57.29	43.48
J-3130	G4-85	8.00	643	62.58	43.73
J-231	DMA0611	10.50	10,718	58.69	44.53
J33963	DMA1106	9.50	25,690	58.13	44.57
J-571	DMA0612	10.49	1,294	58.76	44.69
J-64918	G2-8	8.00	1,600	53.13	44.82
J-1124	DMA1105	9.47	2,179	58.39	45.21
J-3205	DMA0614	7.00	994	57.70	45.41
J-2833	DMA0616	6.50	5,154	57.65	45.85
J63084	DMA1306	6.50	3,010	57.69	45.95
J-1911	DMA1001	9.46	9,288	55.46	45.95
J-3083	G3-1	8.50	118,251	55.37	46.00
J-3192	G1-8	8.00	8,595	62.25	46.14
J-3058	G3-2	8.50	38,016	55.50	46.30
J-2017	DMA0507_2	8.50	6,715	62.71	46.35
J57103	DMA1112	10.00	38,485	59.20	46.46
J-771	DMA1107	8.51	4,323	58.57	46.59
J-3006	G1-2	8.50	109,803	65.56	46.90
J36703	DMA1108	10.20	2,202	59.65	47.45
J-3014	DMA1013	8.50	55,502	65.85	47.58
J-3199	DMA1201	11.00	4,954	64.04	48.22

Label	DMA	Elevation (m)	Demand (m^3/day)	Hydraulic Grade (m)	Pressure (m)
J-3128	G4-86	8.50	1,491	66.63	52.45
J-3197	DMA1202_1	9.00	2,003	65.98	54.16
J-3044	G2-4	6.96	46,080	64.59	54.27
J-3201	DMA1203	9.00	818	67.08	55.75
J-2988	DMA1006	10.50	538	70.87	57.58
J-3027	G2-6	9.14	23,040	70.82	58.83
J-3029	G2-2	6.89	12,973	66.54	58.99
J-3026	DMA1011	8.50	1,262	70.62	61.00
J-3021	G2-3	8.16	15,360	71.78	62.90

Results of Hydraulic Analysis (Pipe)

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-723	J-7	J-8	300	0.2	22.43	0.00	110	0.00
P-718	J-8	J-7	250	0.2	9.57	0.00	110	0.00
P-717	J-8	J-7	300	0.2	12.87	0.00	110	0.00
P-1969	J-11	J-12	500	0.2	0.00	0.00	130	0.00
P-1716	J-19	J-20	300	0.3	3617.57	0.59	130	1.29
P-1627	J-19	J-20	250	0.3	2239.55	0.53	130	1.29
P-930	J-21	J-22	250	0.3	1222.60	0.29	110	0.57
P-1192	J-23	J-24	250	0.4	1551.04	0.37	110	0.89
P-856	J-25	J-26	450	0.4	2329.30	0.17	110	0.10
P-1316	J-265	J-46(1)	250	0.4	12374.84	2.92	130	30.39
P-677	J-33	J-34	300	0.4	0.01	0.00	110	0.00
P-143	J-35	J-36	300	0.4	0.00	0.00	110	0.00
P-598	J-37	J-38	300	0.4	0.00	0.00	130	0.00
P-1397	J-39	J-40	250	0.4	2049.19	0.48	110	1.48
P-1219	J-41(1)	J-42(1)	400	0.4	4116.80	0.38	110	0.55
P-2960	J-43(1)	J-44(1)	250	0.4	12523.99	2.95	110	42.33
P-142	J-47	J-48	400	0.5	0.00	0.00	130	0.00
P-393	J-49	J-50(1)	300	0.5	0.00	0.00	110	0.00
P-253	J-55	J-56	300	0.5	0.00	0.00	130	0.00
P-399	J-57	J-58	300	0.5	0.00	0.00	110	0.00
P-2203	J-59	J-60	250	0.5	4182.18	0.99	130	4.07
P-1398	J-63	J-64	250	0.5	2049.19	0.48	110	1.48
P-186	J-65	J-66	300	0.5	0.00	0.00	130	0.00
P-418	J-67	J-68	300	0.5	0.00	0.00	130	0.00
P-454	J-554	J-555	300	0.5	0.00	0.00	130	0.00
P-363	J-81	J-82	250	0.5	0.00	0.00	110	0.00
P-983	J-83	J-84	250	0.5	1276.65	0.30	110	0.62
P-1506	J-1785	J-567	300	0.5	2685.45	0.44	130	0.74
P-579	J-85	J-86	300	0.5	0.00	0.00	110	0.00
P-374	J-87	J-88	250	0.5	0.00	0.00	110	0.00
P-382	J-89	J-90	250	0.5	0.00	0.00	110	0.00
P-322	J-91	J-92	250	0.5	0.00	0.00	110	0.00
P-2324_SPL2	J51501	J-1244	300	0.5	5317.46	0.87	130	2.62
P-478	J-376	J-377	250	0.5	0.00	0.00	130	0.00
P-195	J-95	J-96	300	0.6	0.00	0.00	130	0.00
P-2819	J-97	J-98	250	0.6	9478.44	2.23	110	25.26
P-477	J-151	J-152	250	0.6	4728.07	1.11	130	5.11
P-2756	J-99	J-100	300	0.6	0.00	0.00	130	0.00
P-246	J-101	J-102	250	0.6	0.00	0.00	110	0.00
P-1135	J-105	J-106	250	0.6	1477.98	0.35	110	0.81
P-1069	J-107	J-108	300	0.6	1751.59	0.29	110	0.46
P-545	J-268	J-381	250	0.6	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-165	J-117	J-118	300	0.6	0.00	0.00	110	0.00
P-1777	J-119	J-120	300	0.6	3865.60	0.63	130	1.45
P-2223	J-121	J-122	300	0.6	6371.15	1.04	110	4.99
P-711	J-125	J-126	250	0.6	0.00	0.00	110	0.00
P-712	J-125	J-126	250	0.6	0.00	0.00	110	0.00
P-1250	J-129	J-130	250	0.6	0.00	0.00	130	0.00
P-1399	J-131	J-132	250	0.6	2049.19	0.48	110	1.49
P-701	J-111	J-112	500	0.7	0.00	0.00	130	0.00
P-412	J-137	J-138	300	0.7	0.00	0.00	130	0.00
P-679	J-139	J-140	300	0.7	0.01	0.00	110	0.00
P-984	J-141	J-142	250	0.7	1276.65	0.30	110	0.62
P-2931	J-143	J-144	400	0.7	14012.80	1.29	130	3.88
P-1136	J-147	J-148	250	0.7	1477.98	0.35	110	0.81
P-1330	J-149	J-150	300	0.7	2169.18	0.36	110	0.68
P-675	J-665	J-666	250	0.7	1921.19	0.45	130	0.97
P-1137	J-153	J-154	250	0.7	1477.98	0.35	110	0.81
P-303	J-155	J-156	250	0.7	0.00	0.00	130	0.00
P-2182	J-157	J-158	250	0.7	4429.20	1.04	130	4.53
P-3007	J-161	J-162	250	0.7	16066.56	3.79	110	67.13
P-2070	J-523	J-524	300	0.8	5188.80	0.85	130	2.50
P-431	J-163	J-164	300	0.8	0.00	0.00	130	0.00
P-375	J-167	J-168	250	0.8	0.00	0.00	110	0.00
P-333	J-169	J-170	250	0.8	0.00	0.00	110	0.00
P-1909	J-17	J-18	800	0.8	0.00	0.00	130	0.00
P-936	J-173	J-174	250	0.8	6.81	0.00	130	0.00
P-807	J-173	J-174	250	2.8	6.81	0.00	130	0.00
P-188	J-175	J-176	300	0.8	0.00	0.00	110	0.00
P-985	J-185	J-186	250	0.8	1276.65	0.30	110	0.62
P-684	J-382	J-383	250	0.9	0.00	0.00	130	0.00
P-722	J-187	J-188	250	0.9	12.25	0.00	130	0.00
P-719	J-188	J-187	250	0.9	12.25	0.00	130	0.00
P-1400	J-189	J-190	250	0.9	2049.19	0.48	110	1.48
P-587	J-187	J-191	250	0.9	0.00	0.00	130	0.00
P-968	J-192	J-193	300	0.9	1692.34	0.28	110	0.43
P-351	J-196	J-197	250	0.9	0.00	0.00	110	0.00
P-827	J-198	J-199	300	0.9	1200.23	0.20	130	0.17
P-1630	J-200	J-201	250	0.9	2528.28	0.60	110	2.19
P-287	J-206	J-207	300	0.9	0.00	0.00	130	0.00
P-155	J-15	J-16	225	0.9	0.00	0.00	130	0.00
P-2592	J-287	J-2805	600	0.9	47612.26	1.95	130	5.18
P-342	J-212	J-213	250	0.9	0.00	0.00	130	0.00
P-2770_SPL2	J50386	J-490	300	0.9	10802.33	1.77	130	9.72
P-2502	J-216	J-217	800	0.9	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1820	J-218	J-219	300	0.9	4152.00	0.68	130	1.65
P-285	J-71	J-72	300	0.9	4728.07	0.77	130	2.10
P-819	J-771	J-516	500	1.0	4323.20	0.25	130	0.15
P-1138	J-220	J-221	250	1.0	1477.98	0.35	110	0.81
P-920	J-222	J-223	250	1.0	1200.23	0.28	130	0.40
P-503	J-224	J-225	250	1.0	0.00	0.00	130	0.00
P-2782	J-230	J-231	300	1.0	10718.40	1.76	130	9.58
P-153	J-232	J-233	300	1.0	0.00	0.00	130	0.00
P-19	J-234	J-235	800	1.0	0.00	0.00	130	0.00
P-367	J-238	J-239	250	1.0	0.00	0.00	130	0.00
P-324	J-244	J-245	300	1.0	0.00	0.00	130	0.00
P-52	J-246	J-247	400	1.0	0.00	0.00	130	0.00
P-407	J-252	J-253	300	1.0	0.00	0.00	130	0.00
P-433_SPL2	J48175	J-1646	250	1.0	7718.40	1.82	130	12.67
P-184	J-258	J-259	300	1.0	0.00	0.00	110	0.00
P-185	J-260	J-261	300	1.0	0.00	0.00	130	0.00
P-350	J-262	J-263	250	1.0	0.00	0.00	130	0.00
P-797	J-266	J-267	250	1.0	556.13	0.13	130	0.10
P-1003	J-272	J-273	300	1.0	1684.03	0.28	130	0.31
P-385	J-275	J-276	300	1.0	0.00	0.00	130	0.00
P-720	J-284	J-283	250	1.0	12.25	0.00	130	0.00
P-721	J-283	J-284	250	1.0	12.25	0.00	130	0.00
P-402	J-291	J-292	300	1.0	0.00	0.00	130	0.00
P-194	J-297	J-298	300	1.0	0.00	0.00	130	0.00
P-319	J-293	J-294	300	1.0	0.00	0.00	130	0.00
P-532	J-299	J-300	250	1.0	0.00	0.00	130	0.00
P-1032	J-307	J-308	300	1.0	0.00	0.00	130	0.00
P-3039	J-723	J-724	400	1.0	3193.99	0.29	130	0.25
P-426	J-313	J-314	300	1.0	0.00	0.00	130	0.00
P-1128	J-301	J-302	600	1.0	14134.47	0.58	130	0.54
P-2373	J-2868	J-316	300	1.0	6836.85	1.12	130	4.16
P-1916	J-317	J-318	300	1.1	4050.17	0.66	110	2.15
P-91	J-322	J-323	300	1.1	0.00	0.00	110	0.00
P-254	J-324	J-55	300	1.1	0.00	0.00	130	0.00
P-1717	J-325	J-326	1000	1.1	34418.30	0.51	130	0.24
P-568	J-550	J-551	300	1.1	0.00	0.00	130	0.00
P-2800	J-327	J-328	300	1.1	13969.59	2.29	130	15.65
P-809	J-329	J-330	250	1.1	675.51	0.16	110	0.19
P-808	J-329	J-330	250	1.1	675.51	0.16	110	0.19
P-455	J-331	J-332	250	1.1	0.00	0.00	130	0.00
P-66	J-333	J-334	600	1.1	27953.57	1.14	130	1.93
P-134	J-281	J-282	400	1.2	0.00	0.00	130	0.00
P-2940	J-303	J-304	250	1.2	11731.20	2.77	130	27.52

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-408	J-15	J-425	300	1.2	0.00	0.00	130	0.00
P-439	J-339	J-331	250	1.2	0.00	0.00	130	0.00
P-167	J-342	J-343	300	1.2	0.00	0.00	130	0.00
P-3018_SPL1	J-772	J48179	400	1.2	45108.94	4.15	130	33.78
P-2006	J-1271	J-1272	500	1.2	6330.35	0.37	130	0.30
P-885	J-113	J-114	250	1.2	0.00	0.00	130	0.00
P-2540	J-719	J-720	500	1.2	34231.13	2.02	130	6.83
P-289	J-332	J-353	250	1.3	0.00	0.00	130	0.00
P-2252	J-354	J-355	450	1.3	14708.19	1.07	110	3.25
P-2699	J-356	J-357	800	1.3	72020.95	1.66	130	2.74
P-581	J-358	J-359	250	1.3	0.00	0.00	130	0.00
P-2955	J-360	J-361	500	1.3	50931.90	3.00	130	14.26
P-430	J-364	J-365	300	1.3	0.00	0.00	110	0.00
P-2932	J-366	J-143	400	1.3	14012.80	1.29	130	3.87
P-1260	J-368	J-369	250	1.3	1675.42	0.40	130	0.75
P-583	J-434	J-268	250	1.3	0.00	0.00	130	0.00
P-1837	J-370	J-371	250	1.3	2651.62	0.63	130	1.75
P11174	J11173	J11174	200	4.6	0.00	0.00	130	0.00
P-2746	J-206	J-375	1200	1.3	159108.72	1.63	130	1.65
P-1331	J-150	J-378	300	1.3	2169.18	0.36	110	0.68
P-994	J-384	J-385	250	1.4	1351.02	0.32	110	0.68
P-669	J-388	J-389	250	1.4	0.00	0.00	130	0.00
P-699	J-390	J-391	300	1.4	0.01	0.00	110	0.00
P-2225	J-392	J-393	400	1.4	11095.70	1.02	110	3.43
P-981	J-179	J-180	250	1.4	0.00	0.00	130	0.00
P-1838	J-396	J-397	250	1.4	2651.62	0.63	130	1.75
P-2356	J-256	J-257	250	1.4	4392.42	1.04	130	4.46
P-2839	J-400	J-401	400	1.4	30941.38	2.85	130	16.81
P-2902	J-211	J-406	400	1.4	5868.01	0.54	130	0.77
P-364	J-934	J-935	250	1.4	0.00	0.00	130	0.00
P42501	J43798	J43796	300	2.6	0.00	0.00	130	0.00
P-1429	J-407	J-408	250	2.0	1294.40	0.31	130	0.46
P-182	J-409	J-410	300	1.4	0.00	0.00	130	0.00
P-969	J-416	J-417	300	1.4	1692.34	0.28	110	0.43
P-1311	J-419	J-420	500	1.5	9429.90	0.56	130	0.63
P-798	J-421	J-422	250	1.5	556.13	0.13	130	0.10
P-2441	J-426	J-67	300	2.0	7502.40	1.23	130	4.95
P-980	J-177	J-178	250	1.5	0.00	0.00	130	0.00
P-2635	J-402	J-2843	300	1.5	9590.73	1.57	130	7.80
P-1803_SPL2	J50388	J-1330	250	1.5	3680.00	0.87	130	3.21
P-1371	J-763	J-764	250	1.5	1488.51	0.35	130	0.60
P-1372	J-763	J-764	250	1.5	1488.51	0.35	130	0.60
P-485	J-461	J-394	250	1.5	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-520	J-440	J-441	250	1.5	0.00	0.00	130	0.00
P-2561	J-442	J-443	800	1.5	0.00	0.00	130	0.00
P-2503	J-216	J-446	800	1.6	0.00	0.00	130	0.00
P-435	J-451	J-452	250	1.6	0.00	0.00	130	0.00
P50388	J50386	J50387	300	2.3	0.00	0.00	130	0.00
P-2770_SPL3	J50387	J50386	300	1.6	10802.33	1.77	130	9.72
P-584	J-344	J-345	250	1.6	1921.19	0.45	130	0.96
P-381	J-459	J-460	250	1.6	0.00	0.00	130	0.00
P-599	J-462	J-65	300	1.6	0.00	0.00	130	0.00
P-2812	J-463	J-464	300	1.6	20614.40	3.38	110	43.83
P-2440	J-463	J-464	300	4.6	0.00	0.00	110	0.00
P-2135	J-255	J-367	250	2.1	6592.00	1.55	130	9.46
P-468	J-404	J-405	250	1.7	0.00	0.00	130	0.00
P-777	J-236	J-237	300	1.7	3205.13	0.52	130	1.02
P-787	J-467	J-466	300	2.7	0.00	0.00	130	0.00
P-823	J-466	J-467	300	1.7	8049.55	1.32	130	5.64
P-424	J-468	J-469	300	1.7	0.00	0.00	130	0.00
P-2453	J-831	J-718	250	1.7	7988.47	1.88	130	13.51
P-470	J-537	J-538	250	1.7	0.00	0.00	130	0.00
P-1031	J-423	J-424	250	1.7	1937.00	0.46	130	0.98
P-870	J-423	J-424	250	4.0	0.00	0.00	130	0.00
P-2194	J-473	J-472	900	1.7	44794.80	0.81	110	0.88
P-2195	J-472	J-473	900	1.7	44794.80	0.81	110	0.88
P-2303	J-641	J-50(2)	250	1.7	4473.93	1.05	130	4.62
P-578	J-474	J-475	250	1.7	0.00	0.00	130	0.00
P-2124	J-136	J-274	250	1.7	9188.76	2.17	130	17.50
P-472	J-894	J-895	250	1.7	0.00	0.00	130	0.00
P-651	J-734	J-735	250	1.7	0.00	0.00	130	0.00
P-665	J-479	J-480	250	1.7	857.83	0.20	130	0.22
P51498	J51496	J51497	250	4.0	0.00	0.00	130	0.00
P-361_SPL3	J51497	J51496	250	1.8	12248.00	2.89	130	29.81
P-389_SPL1	J-61	J51510	300	1.8	0.00	0.00	130	0.00
P-690	J-1029	J-1030	300	1.8	0.00	0.00	130	0.00
P-509	J-187	J-485	250	1.8	0.00	0.00	130	0.00
P-1139	J-486	J-487	250	1.8	1477.98	0.35	110	0.81
P-539	J-427	J-428	250	1.8	0.00	0.00	130	0.00
P-2556	J-492	J-493	300	2.5	8675.37	1.42	110	8.82
P-2017	J-152	J-146	300	1.8	4728.07	0.77	130	2.10
P-1175	J-495	J-496	250	1.8	1472.19	0.35	110	0.80
P-2636	J-619	J-620	300	1.8	9590.73	1.57	130	7.80
P-762	J-613	J-310	800	6.8	28451.25	0.66	130	0.49
P-26	J-497	J-498	500	1.8	0.00	0.00	130	0.00
P-2907	J-499	J-43(1)	250	2.2	10708.85	2.52	110	31.67

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1056	J-500	J-501	250	1.9	1323.27	0.31	110	0.66
P-529	J-955	J-956	250	1.9	0.00	0.00	130	0.00
P-288	J-502	J-503	250	1.9	0.00	0.00	130	0.00
P-1704	J-504	J-505	500	1.9	10650.24	0.63	110	1.07
P-2535	J-60	J-19	250	1.9	5857.12	1.38	130	7.60
P-3049	J-506	J-507	250	1.9	30288.00	7.14	130	159.42
P-154	J-508	J-509	300	1.9	0.00	0.00	110	0.00
P-1376	J-680	J-681	300	1.9	3009.83	0.49	130	0.91
P-2568_SPL1	J-73	J51504	250	2.4	6028.80	1.42	130	8.02
P-1832	J-512	J-513	400	2.6	6701.70	0.62	110	1.35
P-1070	J-514	J-515	300	1.9	1751.59	0.29	110	0.46
P-814	J-45(1)	J-46(1)	250	1.9	6102.40	1.44	130	8.20
P-1821	J-517	J-218	300	1.9	4152.00	0.68	130	1.66
P-1726	J-518	J-58	1100	1.9	63805.29	0.78	110	0.63
P-1926	J-519	J-520	250	1.9	2789.95	0.66	130	1.92
P-1266	J-27	J-28	1000	1.9	31492.11	0.46	130	0.20
P-2808	J-521	J-522	250	2.5	9051.42	2.13	130	17.02
P-1317	J-181	J-182	250	2.0	6102.40	1.44	130	8.20
P-1089	J-525	J-526	800	2.0	7138.39	0.16	130	0.04
P-526	J-529	J-530	250	2.0	0.00	0.00	130	0.00
P-490	J-531	J-532	250	2.0	0.00	0.00	130	0.00
P51512	J51511	J51510	300	3.5	0.00	0.00	130	0.00
P-389_SPL2	J51510	J51511	300	2.0	0.00	0.00	130	0.00
P-118	J-61	J-62	400	2.0	0.00	0.00	130	0.00
P-117	J-61	J-62	400	2.0	0.00	0.00	130	0.00
P-116	J-61	J-62	400	2.0	0.00	0.00	130	0.00
P-99	J-535	J-536	400	2.0	0.00	0.00	130	0.00
P-1246	J-539	J-540	1400	2.0	57443.49	0.43	130	0.12
P-2305	J-543	J-544	500	2.0	18083.20	1.07	130	2.10
P-1388	J-29	J-30	600	2.0	29964.00	1.23	130	2.20
P-1389	J-516	J-29	600	2.0	29964.00	1.23	130	2.20
P31287	J31286	J31287	225	2.0	6608.00	1.92	130	15.88
P50386	J50384	J50385	225	4.1	0.00	0.00	130	0.00
P21560_SPL3	J50385	J50384	200	2.0	1102.39	0.41	130	1.02
P-1046	J-896	J-897	300	2.1	1132.27	0.19	130	0.15
P-523	J-394	J-395	250	2.1	0.00	0.00	130	0.00
P-2481	J-1870	J-2930	250	2.1	3878.41	0.91	130	3.54
P-1840	J-1050	J-77	250	2.1	2651.62	0.63	130	1.75
P-2187	J-552	J-553	300	2.7	5857.12	0.96	130	3.13
P-2064	J-541	J-542	1000	2.1	56385.85	0.83	130	0.59
P-1375	J-457	J-458	300	2.1	3009.83	0.49	130	0.91
P-282	J-556	J-169	250	2.1	0.00	0.00	110	0.00
P-2767	J-557	J-558	1350	2.1	236571.18	1.91	110	2.65

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1140	J-559	J-560	250	2.1	1477.98	0.35	110	0.81
P-2297	J-386	J-899	300	2.1	6990.47	1.14	130	4.34
P-286	J-565	J-566	300	2.2	0.00	0.00	130	0.00
P-2515	J-1277	J-2901	500	2.2	16876.80	0.99	130	1.84
P-2700	J-2282	J-1690	800	2.2	72020.95	1.66	130	2.75
P-872	J-408	J-571	250	4.6	0.00	0.00	130	0.00
P-1088	J-408	J-571	250	2.2	1294.40	0.31	130	0.47
P-2945_SPL4	J50383	J-1390	250	2.2	11852.79	2.79	130	28.05
P-2295	J-386	J-387	300	2.2	6990.47	1.14	130	4.34
P22337	J-3003	J22939	300	2.2	2729.11	0.45	130	0.76
P-378	J-577	J-578	250	2.2	0.00	0.00	110	0.00
P-2457	J-1909	J-2282	800	2.3	53015.59	1.22	130	1.56
P-92	J-580	J-581	300	2.3	0.00	0.00	110	0.00
P-1097	J-582	J-583	1400	2.3	68424.72	0.51	110	0.22
P-417	J-584	J-585	300	2.3	0.00	0.00	130	0.00
P-715	J-359	J-586	250	5.0	0.00	0.00	130	0.00
P-716	J-359	J-586	250	2.3	0.00	0.00	130	0.00
P-361_SPL2	J51496	J-1278	250	2.3	12248.00	2.89	130	29.81
P-23	J-309	J-310	800	14.9	32851.88	0.76	130	0.64
P51504	J-1070	J51503	250	3.5	0.00	0.00	130	0.00
P-1937_SPL1	J-1070	J51503	250	2.3	2789.95	0.66	130	1.93
P-3019	J-591	J-592	300	2.4	24945.48	4.08	130	45.79
P-843	J-264	J-265	400	2.4	12374.84	1.14	130	3.08
P-1221	J-593	J-594	250	2.4	1741.24	0.41	110	1.10
P-358	J-595	J-596	250	2.4	0.00	0.00	110	0.00
P-2262	J-597	J-598	300	2.4	3478.07	0.57	130	1.19
P-352	J-569	J-570	300	2.4	0.00	0.00	130	0.00
P-2409	J-599	J-600	300	2.4	2127.80	0.35	110	0.65
P-2992	J-1048	J-658	400	2.9	20677.92	1.90	130	7.97
P-1556_SPL1	J-1234	J11169	500	2.4	5870.92	0.35	130	0.26
P-2920	J-604	J-605	1350	2.4	326498.94	2.64	110	4.81
P-937	J-625	J-626	250	2.4	1251.63	0.30	110	0.59
P-2626	J-2891	J-1294	400	2.4	12762.61	1.18	130	3.25
P-1332	J-606	J-378	300	2.4	2169.18	0.36	110	0.68
P-2755	J-878	J-658	400	2.5	20677.92	1.90	130	7.97
P-2695	J-658	J-878	400	4.6	0.00	0.00	130	0.00
P-1747	J-609	J-610	250	4.4	0.00	0.00	110	0.00
P-2041	J-609	J-610	250	2.5	6252.80	1.47	110	11.69
P-334	J-853	J-71	300	2.5	4728.07	0.77	130	2.10
P36703	J36702	J36703	300	2.5	2201.60	0.36	130	0.51
P-48	J-658	J-659	400	2.5	0.00	0.00	130	0.00
P48177	J48173	J48174	250	3.9	0.00	0.00	130	0.00
P-2796_SPL3	J48174	J48173	400	2.5	26613.33	2.45	130	12.71

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2601	J-614	J-499	250	2.5	10708.85	2.52	110	31.67
P-2338	J-614	J-499	250	4.4	0.00	0.00	110	0.00
P-55	J-111	J-796	500	2.5	0.00	0.00	130	0.00
P-1033	J-615	J-616	300	2.5	0.00	0.00	130	0.00
P-2796_SPL2	J48173	J-1107	400	3.2	26613.33	2.45	130	12.71
P-43	J-617	J-618	400	2.5	0.00	0.00	130	0.00
P-2733_SPL2	J50380	J-1695	250	2.5	7571.20	1.79	130	12.23
P-763	J-649	J-650	250	2.5	0.00	0.00	130	0.00
P48182	J48181	J48180	250	5.0	0.00	0.00	130	0.00
P-3000_SPL3	J48181	J48180	300	2.6	22451.20	3.68	130	37.67
P-3000_SPL2	J48180	J-984	300	2.6	22451.20	3.68	130	37.67
P-164	J-623	J-624	300	2.6	0.00	0.00	110	0.00
P-203	J-1127	J-1128	300	2.6	0.00	0.00	130	0.00
P-2443	J-79	J-437	400	2.6	13372.97	1.23	130	3.55
P-1419	J-630	J-631	600	2.6	30867.17	1.26	130	2.32
P36704	J36703	J36704	300	2.6	0.00	0.00	130	0.00
P-2100	J-360	J-325	1200	2.6	69284.06	0.71	130	0.35
P-489	J-632	J-633	300	2.6	0.00	0.00	130	0.00
P-2511	J-621	J-622	800	2.8	64650.03	1.49	130	2.25
P-2399	J-637	J-636	300	2.6	12640.72	2.07	110	17.72
P-2058	J-636	J-637	300	4.8	0.00	0.00	110	0.00
P-366	J-638	J-507	250	2.8	0.00	0.00	130	0.00
P-2263	J-642	J-597	300	2.6	3478.07	0.57	130	1.19
P-1141	J-645	J-646	250	2.6	1477.98	0.35	110	0.81
P-2953	J-506	J-647	250	4.6	0.00	0.00	130	0.00
P-3025	J-647	J-506	250	2.6	30288.00	7.14	130	159.42
P-731	J-267	J-648	250	5.4	0.00	0.00	130	0.00
P-760	J-267	J-648	250	2.6	556.13	0.13	130	0.10
P22327	J-2930	J22323	225	2.7	0.00	0.00	130	0.00
P-670	J-1037	J-1038	250	2.7	1921.19	0.45	130	0.97
P-986	J-83	J-141	250	2.7	1276.65	0.30	110	0.62
P-15	J-77	J-78	250	2.7	0.00	0.00	130	0.00
P-1743	J-653	J-652	250	5.0	0.00	0.00	110	0.00
P-2056	J-652	J-653	250	2.7	6371.15	1.50	110	12.11
P-2314	J-602	J-654	400	2.7	955.99	0.09	130	0.03
P-173	J-454	J-930	300	2.7	0.00	0.00	130	0.00
P-982	J-180	J-177	250	2.7	0.00	0.00	130	0.00
P21560_SPL1	J21557	J50385	200	3.3	1102.39	0.41	130	1.02
P-3048_SPL1	J-1769	J50378	250	3.2	4806.15	1.13	130	5.27
P-776	J-222	J-662	250	6.1	0.00	0.00	130	0.00
P-817	J-662	J-222	250	2.7	1200.23	0.28	130	0.40
P-2438	J-663	J-664	800	2.7	49510.08	1.14	110	1.87
P-1191	J-178	J-179	250	2.7	5633.88	1.33	130	7.08

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P21571	J21569	J21571	300	2.8	0.00	0.00	130	0.00
P-2768	J-669	J-557	1350	2.8	236571.18	1.91	110	2.65
P-778	J-670	J-671	500	2.8	1692.34	0.10	110	0.04
P-2532	J-672	J-673	250	2.8	4429.20	1.04	130	4.53
P-1273	J-674	J-675	300	2.8	3454.93	0.57	130	1.18
P-1957	J-676	J-677	300	2.8	4755.20	0.78	130	2.13
P-170	J-1265	J-1266	300	2.8	0.00	0.00	130	0.00
P-1944_SPL2	J51500	J-1256	250	2.8	2789.95	0.66	130	1.92
P51501	J-1256	J51500	250	4.3	0.00	0.00	130	0.00
P-2158	J-682	J-683	300	5.1	0.00	0.00	110	0.00
P-2474	J-683	J-682	300	2.8	13234.18	2.17	110	19.29
P-2445	J-2151	J-437	400	2.8	13372.97	1.23	130	3.55
P-181	J-684	J-685	300	2.8	0.00	0.00	130	0.00
P-2752	J-686	J-687	250	4.0	8048.72	1.90	110	18.66
P-868	J-689	J-688	300	2.8	1923.20	0.31	130	0.40
P-793	J-688	J-689	300	6.3	0.00	0.00	130	0.00
P-2985_SPL4	J48178	J-1808	300	2.8	20326.40	3.33	130	31.34
P-2862	J-690	J-691	250	3.8	9901.18	2.33	110	27.39
P20484	J21541	J21542	225	4.4	0.00	0.00	130	0.00
P-1319	J-208	J-209	500	5.3	0.00	0.00	130	0.00
P-1748	J-209	J-208	500	2.8	17390.00	1.03	130	1.95
P-2786	J-692	J-669	1350	2.8	250932.69	2.03	110	2.95
P-2798	J-702	PochentongWT	400	2.8	50505.73	4.65	130	41.64
P-522	J-533	J-534	250	2.9	0.00	0.00	130	0.00
P-1004	J-693	J-694	300	2.9	1684.03	0.28	130	0.31
P-764	J-51(1)	J-52	250	2.9	0.00	0.00	130	0.00
P-2410	J-695	J-696	300	2.9	2127.80	0.35	110	0.65
P-2820	J-682	J-697	300	4.1	13234.18	2.17	110	19.29
P-1318	J-182	J-113	250	2.9	6102.40	1.44	130	8.20
P-3044	J-698	J-699	400	2.9	10604.99	0.98	130	2.31
P-2799	J-723	J-702	400	2.9	50505.73	4.65	130	41.64
P-2306	J-707	J-708	500	2.9	18083.20	1.07	130	2.10
P22326	J-2930	J22322	110	2.9	0.00	0.00	130	0.00
P-2883	J-709	J-710	250	2.9	8881.60	2.09	130	16.44
P-383	J-711	J-712	250	2.9	0.00	0.00	110	0.00
P-2921	J-605	J-692	1350	2.9	326498.94	2.64	110	4.81
P-1071	J-713	J-714	300	2.9	1751.59	0.29	130	0.34
P-1644	J-715	J-716	250	4.1	1915.34	0.45	110	1.31
P-852	J-2812	J-2875	600	3.0	4948.92	0.20	130	0.08
P-2472	J-691	J-721	250	3.0	9901.18	2.33	110	27.39
P-2257	J-721	J-691	250	4.5	0.00	0.00	110	0.00
P-433_SPL3	J48176	J48175	250	3.0	7718.40	1.82	130	12.68
P48178	J48176	J48175	250	6.9	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2075	J-1254	J-1255	500	3.0	20534.51	1.21	130	2.65
P-510	J-722	J-187	250	3.1	0.00	0.00	130	0.00
P-2153	J-120	J-729	250	3.0	3865.60	0.91	130	3.52
P-2349	J-730	J-731	300	5.4	0.00	0.00	110	0.00
P-2620	J-730	J-731	300	3.0	15635.17	2.56	110	26.26
P-938	J-732	J-733	250	3.0	1251.63	0.30	110	0.59
P-2910	J-951	J-772	400	3.0	17975.95	1.66	130	6.15
P-2810	J-23	J-737	250	3.0	8783.17	2.07	110	21.94
P-86	J-738	J-739	300	3.0	0.00	0.00	110	0.00
P-1819	J-839	J-2204	250	3.0	3205.13	0.76	130	2.49
P-678	J-725	J-726	250	3.0	3955.18	0.93	130	3.68
P-174	J-742	J-743	300	3.0	0.00	0.00	130	0.00
P-1220	J-744	J-41(1)	400	3.0	4116.80	0.38	110	0.55
P-2312	J-745	J-746	250	3.0	9034.87	2.13	110	23.12
P-2040	J-745	J-746	250	4.9	0.00	0.00	110	0.00
P-513	J-936	J-937	250	3.3	0.00	0.00	130	0.00
P-2980	J-747	J-748	600	3.1	86759.25	3.55	130	15.74
P-306	J-527	J-528	250	3.1	0.00	0.00	130	0.00
P-710	J-749	J-339	250	5.0	2.89	0.00	130	0.00
P-709	J-749	J-339	250	3.1	2.89	0.00	130	0.00
P-329	J-277	J-278	300	3.1	0.00	0.00	130	0.00
P-1381	J-28	J-736	1000	3.1	36486.66	0.54	130	0.26
P-2727	J-181	J-374	300	3.1	6408.25	1.05	130	3.70
P-1134	J-255	J-254	250	7.6	0.00	0.00	130	0.00
P-1707	J-254	J-255	250	3.1	6592.00	1.55	130	9.46
P-335	J-752	J-753	250	3.1	0.00	0.00	110	0.00
P-2822	J-291	J-754	1400	3.1	307712.45	2.31	130	2.65
P-893	J-755	ChrangChamresWT	400	3.1	33258.58	3.06	130	19.21
P-1303	J-757	J-758	250	3.1	1191.17	0.28	110	0.54
P-2506	J-759	J-760	600	3.1	36630.40	1.50	130	3.19
P-1395	J-424	J-1334	250	3.1	1937.00	0.46	130	0.98
P11177	J11176	J11172	250	4.1	0.00	0.00	130	0.00
P-2143	J-346	J-347	250	3.1	2977.02	0.70	130	2.17
P-2998	J-765	J-766	250	4.4	15249.32	3.60	110	60.95
P-2470	J-747	J-767	600	3.1	36355.11	1.49	130	3.14
P-3018_SPL2	J48179	J-773	400	3.1	45108.94	4.15	130	33.78
P-1927	J-774	J-775	250	3.2	2789.95	0.66	130	1.93
P-765	J-51(1)	J-1237	250	3.2	0.00	0.00	130	0.00
P-2913	J-776	J-777	250	4.2	10851.21	2.56	110	32.46
P-873	J-779	J-778	300	6.8	0.00	0.00	130	0.00
P-1092	J-778	J-779	300	3.2	4366.73	0.72	130	1.82
P-2382	J-780	J-230	300	3.2	10718.40	1.76	130	9.58
P-2069	J-230	J-780	300	5.5	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1942	J-781	J-782	250	3.2	2789.95	0.66	130	1.93
P51510	J51508	J51509	300	5.8	0.00	0.00	130	0.00
P-2394_SPL3	J51509	J51508	400	3.2	12704.18	1.17	130	3.23
P-414	J-783	J-784	300	3.2	2838.95	0.46	130	0.82
P-2065	J-655	J-305	1000	3.2	56385.85	0.83	130	0.59
P-895	J-45(1)	J-113	250	3.2	6102.40	1.44	130	8.20
P-1839	J-787	J-370	250	3.2	2651.62	0.63	130	1.75
P-2046	J-788	J-789	250	2.3	3052.89	0.72	130	2.27
P-326	J-790	J-791	250	3.3	0.00	0.00	110	0.00
P33970_SPL2	J36702	J-3209	600	3.3	32165.60	1.32	130	2.51
P-1274	J-678	J-679	300	3.3	3454.93	0.57	130	1.18
P-1057	J-712	J-797	250	3.7	1323.27	0.31	110	0.66
P-708	J-94	J-415	250	5.0	0.00	0.00	130	0.00
P-707	J-94	J-415	250	3.3	0.00	0.00	130	0.00
P-1282	J-601	J-311	300	3.3	3354.47	0.55	130	1.11
P-2073	J-800	J-801	250	3.3	3741.52	0.88	110	4.52
P-1222	J-594	J-802	250	3.3	1741.24	0.41	110	1.10
P-340	J-847	J-848	250	3.3	0.00	0.00	130	0.00
P-2690	J-805	J-806	250	3.4	11414.18	2.69	110	35.64
P-2458	J-805	J-806	250	5.8	0.00	0.00	110	0.00
P-171	J-56	J-807	300	3.4	0.00	0.00	130	0.00
P-1876	J-2908	J-2909	600	3.4	21722.75	0.89	130	1.21
P-2985_SPL2	J48177	J48178	300	3.4	20326.40	3.33	130	31.34
P48179	J48177	J48178	250	6.4	0.00	0.00	130	0.00
P-820	J-810	J-809	300	3.4	1684.03	0.28	130	0.31
P-788	J-809	J-810	300	5.3	0.00	0.00	130	0.00
P-2473	J-811	J-812	300	4.6	0.00	0.00	130	0.00
P-2619	J-811	J-812	300	3.4	0.00	0.00	130	0.00
P-3016	J-777	J-1515	200	3.4	10851.21	4.00	110	96.24
P-1682	J-813	J-426	250	5.5	2429.45	0.57	130	1.49
P-2053	J-813	J-426	300	3.4	5072.94	0.83	130	2.40
P-1768	J-814	J-49	300	3.4	4039.43	0.66	110	2.14
P-2487	J-817	J-818	800	3.4	60338.71	1.39	130	1.98
P-301	J-819	J-820	300	3.4	0.00	0.00	130	0.00
P-463	J-821	J-822	250	3.4	0.00	0.00	110	0.00
P-2995	J-825	J-826	400	3.4	3379.10	0.31	130	0.28
P-714	J-72	J-151	250	3.5	2364.04	0.56	130	1.42
P-713	J-72	J-151	250	3.5	2364.04	0.56	130	1.42
P-1034	J-827	J-828	300	3.5	0.00	0.00	130	0.00
P-2733_SPL3	J50381	J50380	250	3.5	7571.20	1.79	130	12.23
P50382	J50380	J50381	250	6.1	0.00	0.00	130	0.00
P-3050	J-829	J-647	250	3.5	30288.00	7.14	130	159.42
P-1786	J-430	J-431	600	3.5	7718.40	0.32	130	0.18

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-3058	J-724	PochentongWT	400	3.5	66272.25	6.10	130	68.87
P-2669	J-830	J-765	250	5.5	0.00	0.00	110	0.00
P-2801	J-830	J-765	250	3.5	15249.32	3.60	110	60.95
P-238	J-832	J-833	250	3.5	0.00	0.00	110	0.00
P-1281	J-311	J-312	300	3.5	3354.47	0.55	130	1.11
P-1422	J-835	J-831	300	5.7	0.00	0.00	130	0.00
P-1650	J-835	J-831	250	3.5	7988.47	1.88	130	13.51
P-791	J-616	J-327	300	5.5	0.00	0.00	130	0.00
P-824	J-616	J-327	300	3.5	0.00	0.00	130	0.00
P-2698	J-841	J-842	250	3.5	6090.23	1.44	130	8.17
P-2391	J-841	J-842	250	7.0	0.00	0.00	130	0.00
P-886	J-114	J-45(1)	250	4.5	0.00	0.00	130	0.00
P-2969	J-843	J-366	250	5.5	0.00	0.00	130	0.00
P-3012	J-843	J-366	250	3.5	14012.80	3.30	130	38.25
P-2039	J-844	J-687	250	5.6	0.00	0.00	110	0.00
P-2304	J-687	J-844	250	3.5	8048.72	1.90	110	18.66
P-1929	J-1069	J-1070	250	3.5	2789.95	0.66	130	1.92
P-2970	J-1111	J-2830	400	3.5	36447.92	3.36	130	22.76
P-902	J-849	J-850	250	3.6	244.27	0.06	110	0.03
P-200	J-851	J-852	300	3.6	0.00	0.00	130	0.00
P-2567	J-145	J-854	300	3.6	8680.01	1.42	130	6.48
P-806	J-855	J-856	250	3.6	244.27	0.06	110	0.03
P-785	J-855	J-856	250	5.5	0.00	0.00	110	0.00
P-2684	J-3155	J-3156	400	3.6	17756.80	1.64	130	6.01
P-1941	J-398	J-399	250	3.6	2789.95	0.66	130	1.93
P-2088_SPL3	J51499	J51498	300	3.6	3947.94	0.65	130	1.51
P51500	J51498	J51499	300	8.3	0.00	0.00	130	0.00
P-2211	J-857	J-858	500	3.6	18201.39	1.07	110	2.89
P-1894	J-861	J-862	250	3.6	3213.43	0.76	110	3.41
P-2641	J-411	J-412	250	3.6	6592.00	1.55	130	9.46
P-1312	J-870	J-419	500	3.7	9429.90	0.56	130	0.63
P-1528	J-871	J-121	300	3.7	3157.72	0.52	110	1.36
P-179	J-872	J-873	300	3.7	0.00	0.00	130	0.00
P-2803	J-874	J-875	300	3.7	12704.18	2.08	130	13.12
P51506	J51505	J51504	225	6.4	0.00	0.00	130	0.00
P-2568_SPL2	J51504	J51505	250	3.7	6028.80	1.42	130	8.02
P-1928	J-876	J-877	250	3.7	2789.95	0.66	130	1.92
P-967	J-880	J-881	300	3.7	1692.34	0.28	110	0.43
P-2604	J-883	J-882	250	5.9	0.00	0.00	110	0.00
P-2745	J-882	J-883	250	3.7	14067.95	3.32	110	52.49
P-1333	J-884	J-885	300	3.8	2169.18	0.36	110	0.68
P-1550	J-950	J-1422	250	3.8	1771.98	0.42	130	0.83
P-475	J-914	J-915	250	3.8	1921.19	0.45	130	0.97

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1142	J-886	J-887	250	3.8	1477.98	0.35	110	0.81
P-736	J-924	J-925	300	3.8	0.01	0.00	130	0.00
P-1374	J-372	J-373	500	3.8	11080.94	0.65	130	0.85
P-1035	J-828	J-888	300	3.8	0.00	0.00	130	0.00
P-2291_SPL1	J-891	J42473	500	3.8	17390.00	1.03	130	1.95
P-735	J-794	J-795	300	3.8	0.01	0.00	130	0.00
P-874	J-493	J-892	300	6.3	0.00	0.00	110	0.00
P-929	J-493	J-892	300	3.8	2235.03	0.37	110	0.72
P-3041	J-1362	J-2864	400	3.8	56517.29	5.21	130	51.29
P-1796	J-690	J-893	800	3.9	27545.50	0.63	110	0.63
P-401	J-566	J-898	300	3.9	0.00	0.00	130	0.00
P-2296	J-899	J-900	300	3.9	6990.47	1.14	130	4.34
P-2520	J-901	J-709	250	3.9	8881.60	2.09	130	16.44
P-2334	J-709	J-901	250	6.0	0.00	0.00	130	0.00
P-2253	J-904	J-905	450	3.9	14708.19	1.07	110	3.25
P-2183	J-673	J-157	250	3.9	4429.20	1.04	130	4.53
P-2878	J-2795	J-719	500	3.9	23428.80	1.38	130	3.39
P-2945_SPL2	J50382	J50383	250	3.9	11852.79	2.79	130	28.05
P50384	J50382	J50383	250	6.1	0.00	0.00	130	0.00
P-1639	J-553	J-906	300	3.9	5857.12	0.96	130	3.13
P-1286	J-553	J-906	300	6.1	0.00	0.00	130	0.00
P-2192	J-522	J-907	250	5.8	0.00	0.00	130	0.00
P-2408	J-522	J-907	250	3.9	9051.42	2.13	130	17.02
P-2624	J-1123	J-1124	600	3.9	24538.41	1.00	130	1.52
P-110	J-908	J-909	300	3.9	0.00	0.00	130	0.00
P-572	J-910	J-911	300	3.9	0.00	0.00	110	0.00
P-2078	J-660	J-661	300	3.9	3947.94	0.65	130	1.51
P-427	J-916	J-917	300	4.0	0.00	0.00	130	0.00
P-2828	J-920	J-919	250	4.0	16066.56	3.79	110	67.14
P-2665	J-919	J-920	250	7.4	0.00	0.00	110	0.00
P-2679	J-373	J-934	300	4.0	9918.40	1.62	130	8.30
P-950	J-921	J-922	300	4.0	1741.23	0.29	110	0.45
P-3008	J-162	J-920	250	5.2	16066.56	3.79	110	67.14
P-664	J-923	J-434	250	4.0	0.00	0.00	130	0.00
P-2642	J-750	J-411	250	4.0	6592.00	1.55	130	9.46
P41933	J-136	J-133	250	4.0	9188.76	2.17	130	17.51
P57099	J56924	J56925	250	4.0	0.00	0.00	130	0.00
P-2510	J-860	J-432	250	4.0	9573.99	2.26	130	18.89
P-2240	J-860	J-432	250	7.1	0.00	0.00	130	0.00
P-2136	J-750	J-254	250	5.2	6592.00	1.55	130	9.46
P-2976	J-932	J-933	250	4.0	13752.00	3.24	130	36.94
P-458	J-428	J-988	250	4.0	0.00	0.00	130	0.00
P-2052	J-938	J-939	400	8.2	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2437	J-939	J-938	400	4.0	21566.32	1.99	130	8.61
P-2484	J-838	J-943	500	4.1	22225.91	1.31	110	4.19
P-2732	J-944	J-945	250	6.1	0.00	0.00	110	0.00
P-2818	J-944	J-945	250	4.1	13711.63	3.23	110	50.06
P-346_SPL2	J51506	J-1805	250	5.5	7816.01	1.84	130	12.97
P-537	J-419	J-946	250	4.1	0.00	0.00	130	0.00
P-231	J-947	J-948	250	4.1	0.00	0.00	110	0.00
P-1284	J-601	J-319	300	4.1	3354.47	0.55	130	1.11
P-1787	J-541	J-430	600	4.1	7718.40	0.32	130	0.18
P-2226	J-838	J-392	400	4.1	11095.70	1.02	110	3.43
P-3002	J-1116	J-1022	300	4.2	22451.20	3.68	130	37.67
P-3052	J-328	J-952	250	4.2	33715.19	7.95	130	194.43
P-2879_SPL3	J48185	J31283	300	4.2	15038.40	2.46	130	17.94
P48186	J48185	J31283	300	6.8	0.00	0.00	130	0.00
P-2189	J-953	J-954	300	4.5	3650.16	0.60	110	1.78
P-1756	J-579	J-179	250	4.2	5633.88	1.33	130	7.08
P51503	J51502	J51501	300	6.8	0.00	0.00	130	0.00
P-2324_SPL3	J51502	J51501	300	4.3	5317.46	0.87	130	2.61
P-524	J-912	J-913	250	4.3	0.00	0.00	130	0.00
P-56	J-1154	J-111	500	4.3	0.00	0.00	130	0.00
P-2865	J-859	J-860	250	6.0	9573.99	2.26	130	18.89
P-1483	J-779	J-963	300	4.3	4366.73	0.72	130	1.82
P-1183	J-966	J-967	300	4.3	3741.52	0.61	110	1.86
P-933	J-966	J-967	300	7.0	0.00	0.00	110	0.00
P-789	J-2967	J-2215	400	4.3	346.67	0.03	110	0.01
P-2602	J-970	J-730	400	5.2	15635.17	1.44	110	6.47
P-1943	J-1256	J-1257	250	4.3	2789.95	0.66	130	1.93
P-2286	J-838	J-393	400	5.5	11130.22	1.03	110	3.45
P46775	J11176	J11175	250	7.1	0.00	0.00	130	0.00
P11176	J11175	J11176	250	4.3	0.00	0.00	130	0.00
P-2942	J-812	J-971	300	6.0	0.00	0.00	130	0.00
P-1868	J-928	J-929	250	4.3	2685.45	0.63	130	1.79
P-2063	J-305	J-306	1000	4.3	56385.85	0.83	130	0.59
P-18	J-972	J-973	900	4.3	0.00	0.00	130	0.00
P-2009	J-954	J-974	250	4.4	3650.16	0.86	110	4.31
P-1745	J-954	J-974	250	6.9	0.00	0.00	110	0.00
P-1986	J-975	J-976	450	4.4	17957.12	1.31	110	4.71
P-1643	J-976	J-975	450	7.9	0.00	0.00	110	0.00
P-2949	J-842	J-977	250	4.4	6090.23	1.44	130	8.17
P-1762	J-978	J-979	800	4.5	45424.88	1.05	130	1.17
P-2703	J-686	J-980	250	4.4	7353.50	1.73	110	15.79
P-409	J-981	J-982	300	4.4	0.00	0.00	130	0.00
P51508	J51506	J51507	250	6.5	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-346_SPL3	J51507	J51506	250	4.4	7816.01	1.84	130	12.97
P-987	J-142	J-985	250	4.5	1276.65	0.30	110	0.62
P-1757	J-178	J-264	250	4.4	5633.88	1.33	130	7.07
P-297	J-986	J-987	250	4.4	0.00	0.00	110	0.00
P39446	J-2790	J41841	300	4.4	5857.71	0.96	130	3.13
P-1030	J-990	J-991	300	4.5	4366.73	0.72	130	1.82
P-890	J-990	J-991	300	6.7	0.00	0.00	130	0.00
P-1143	J-992	J-993	250	4.5	1477.98	0.35	110	0.81
P46770	J47792	J47791	250	6.7	0.00	0.00	130	0.00
P-531	J-988	J-989	250	4.5	0.00	0.00	130	0.00
P-1782	J-1157	J-256	250	4.5	4392.42	1.04	130	4.46
P-1396	J-256	J-1157	250	7.2	0.00	0.00	130	0.00
P-1334	J-996	J-997	300	4.5	2169.18	0.36	110	0.68
P-1174	J-513	J-1000	300	7.1	0.00	0.00	110	0.00
P-1564	J-513	J-1000	400	4.5	6701.70	0.62	110	1.35
P-1758	J-374	J-579	250	4.5	5633.88	1.33	130	7.07
P-2924	J-1001	J-1002	1000	4.5	153042.18	2.26	130	3.74
P-1202	J-998	J-999	500	4.6	6978.20	0.41	130	0.36
P-2926	J-2	J-1007	1000	4.6	154670.29	2.28	130	3.81
P-2386	J-289	J-290	400	4.6	13674.45	1.26	130	3.70
P-2840	J-400	J-1004	400	4.6	30941.38	2.85	130	16.80
P-1187	J-1034	J-1035	300	4.6	1771.97	0.29	130	0.34
P-2004	J-1281	J-257	300	4.6	4392.42	0.72	130	1.84
P-2379	J-3054	J-3055	400	4.6	12212.80	1.12	130	3.00
P-1259	J-264	J-823	400	4.6	23764.99	2.19	130	10.31
P-1258	J-823	J-824	400	4.7	23764.99	2.19	130	10.31
P-667	J-1011	J-1012	250	4.7	1921.19	0.45	130	0.96
P-2784	J-636	J-1013	300	6.1	12640.72	2.07	110	17.72
P-1335	J-1014	J-1015	300	4.7	2169.18	0.36	110	0.68
P-3001	J-1022	J-983	300	4.7	22451.20	3.68	130	37.67
P-2407	J-737	J-1018	250	4.7	8783.17	2.07	110	21.94
P-2196	J-737	J-1018	250	6.9	0.00	0.00	110	0.00
P-357	J-981	J-1019	300	4.7	0.00	0.00	130	0.00
P-17	J-1023	J-1024	1250	4.7	0.00	0.00	110	0.00
P-2760	J-746	J-1025	250	4.7	9034.87	2.13	110	23.12
P-2099	J-717	J-718	300	4.7	8967.14	1.47	130	6.88
P-491	J-789	J-1031	250	2.4	0.00	0.00	130	0.00
P-2157	J-1036	J-900	250	4.8	3897.60	0.92	130	3.58
P-1558	J-2970	J-2220	800	4.8	26587.83	0.61	130	0.43
P-460	J-1039	J-1040	250	4.8	0.00	0.00	110	0.00
P-2935	J-1041	J-1042	300	4.8	18201.39	2.98	110	34.80
P-1866	J-454	J-1233	300	4.8	5750.09	0.94	130	3.02
P-2753	J-844	J-1043	250	6.9	8048.72	1.90	110	18.66

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2809	J-907	J-1044	250	6.6	9051.42	2.13	130	17.02
P-2740	J-1045	J-1046	1000	4.8	131231.89	1.93	110	3.83
P-2977	J-933	J-31	250	4.8	13752.00	3.24	130	36.94
P-1803_SPL3	J50389	J50388	250	4.8	3680.00	0.87	130	3.21
P50390	J50389	J50388	250	8.0	0.00	0.00	130	0.00
P-2031	J-356	J-1047	800	4.9	21452.81	0.49	130	0.29
P-2590	J-1049	J-939	400	5.9	14990.33	1.38	130	4.39
P-2729	J-1051	J-1044	250	4.9	7376.00	1.74	130	11.65
P-784	J-1052	J-1053	450	4.9	406.88	0.03	110	0.00
P-761	J-1052	J-1053	400	6.8	0.00	0.00	110	0.00
P-511	J-1321	J-940	250	4.9	0.00	0.00	130	0.00
P-1296	J-1054	J-1055	250	4.9	1191.17	0.28	110	0.54
P-2043_SPL2	J21552	J-1494	400	4.9	7608.16	0.70	130	1.25
P-1842	J-1167	J-1168	250	4.9	2651.62	0.63	130	1.75
P-175	J-677	J-1056	300	4.9	0.00	0.00	130	0.00
P-2188	J-20	J-906	300	4.9	5857.12	0.96	130	3.13
P-811	J-1057	J-1058	300	7.4	0.00	0.00	130	0.00
P-841	J-1058	J-1057	300	4.9	16222.52	2.66	130	20.64
P-813	J-1059	J-1060	250	4.9	1351.02	0.32	110	0.68
P-796	J-1060	J-1059	250	5.9	0.00	0.00	110	0.00
P-2581	J-1061	J-652	250	7.1	6371.15	1.50	110	12.11
P-2908	J-1062	J-614	250	7.1	10708.85	2.52	110	31.67
P-2392	J-1065	J-1066	400	5.0	12704.18	1.17	130	3.23
P-1239	J-881	J-1067	250	5.0	1692.34	0.40	110	1.04
P-163	J-1071	J-1072	300	5.0	0.00	0.00	110	0.00
P-876	J-1074	J-1075	500	5.0	3443.92	0.20	110	0.13
P-706	J-1076	J-1077	250	5.0	0.00	0.00	110	0.00
P-705	J-1076	J-1077	250	7.4	0.00	0.00	110	0.00
P-1304	J-1078	J-1079	250	5.0	1191.17	0.28	110	0.54
P-508	J-1080	J-212	250	5.0	0.00	0.00	130	0.00
P-368	J-1077	J-1081	250	5.0	0.00	0.00	110	0.00
P-403	J-248	J-249	300	5.0	0.00	0.00	130	0.00
P-126	J-1082	J-1083	300	5.1	0.00	0.00	110	0.00
P-1679	J-1084	J-1085	500	5.1	9681.19	0.57	130	0.66
P-1527	J-1084	J-1085	500	6.6	8402.01	0.50	130	0.51
P-1129	J-302	J-1478	600	5.6	14134.47	0.58	130	0.55
P-1803_SPL1	J-808	J50389	250	5.1	3680.00	0.87	130	3.22
P-1833	J-1000	J-1088	400	7.1	6701.70	0.62	110	1.35
P-1291	J-1089	J-1090	250	5.1	3213.43	0.76	110	3.41
P-1091	J-1090	J-1089	250	10.1	0.00	0.00	110	0.00
P-2259	J-798	J-799	600	5.1	29551.03	1.21	130	2.14
P-1124	J-1091	J-689	300	5.1	1923.20	0.31	130	0.40
P-1895	J-1092	J-1093	250	5.1	3213.43	0.76	110	3.41

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P21569	J21568	J21569	400	5.2	40712.00	3.75	130	27.94
P-2705	J-1096	J-1097	250	5.2	2127.80	0.50	110	1.59
P-1687	J-325	J-1098	1200	5.2	34865.76	0.36	130	0.10
P-226	J-699	J-1099	400	5.2	52479.90	4.83	130	44.71
P-2400	J-1100	J-602	400	5.2	0.00	0.00	130	0.00
P-1401	J-1102	J-1103	250	5.2	2049.19	0.48	110	1.48
P-1831	J-1043	J-1104	800	5.2	29197.58	0.67	110	0.70
P-1841	J-1105	J-1106	250	5.2	2651.62	0.63	130	1.75
P-2140	J-2916	J-1418	400	5.2	10090.99	0.93	130	2.11
P-854	J-458	J-1068	300	9.9	0.00	0.00	130	0.00
P-1052	J-458	J-1068	300	5.2	3009.83	0.49	130	0.91
P50381	J50378	J50379	250	9.5	0.00	0.00	130	0.00
P-3048_SPL2	J50378	J50379	250	5.2	4806.15	1.13	130	5.27
P-2507	J-1108	J-759	600	5.4	36630.40	1.50	130	3.19
P-2609	J-1109	J-1110	400	5.3	16405.88	1.51	110	7.07
P-1043	J-1193	J-1194	300	5.3	1344.88	0.22	130	0.21
P-2946	J-1390	J-1391	250	5.7	11852.79	2.79	130	28.05
P-3046	J-629	J-423	250	7.3	26920.17	6.35	130	128.15
P-2357	J-512	J-766	1000	5.4	83178.83	1.23	110	1.65
P-860	J-2539	J-2148	300	5.4	0.00	0.00	130	0.00
P-2868	J-1179	J-1313	250	5.4	10013.04	2.36	130	20.52
P-2255	J-1122	J-904	450	5.4	14708.19	1.07	110	3.25
P-242	J-1099	ChaomChaoWT	400	5.5	52479.90	4.83	130	44.71
P-1529	J-1125	J-1126	250	5.5	1771.97	0.42	130	0.83
P-3059	ChaomChaoWT	J-698	400	5.5	74570.39	6.87	130	85.69
P-2680	J-934	J-404	300	5.5	9918.40	1.62	130	8.30
P-1015	J-1130	J-1131	300	5.5	1684.03	0.28	130	0.31
P-883	J-1132	J-593	250	5.5	1741.24	0.41	110	1.10
P-850	J-593	J-1132	250	7.5	0.00	0.00	110	0.00
P-903	J-1135	J-1136	250	5.5	244.27	0.06	110	0.03
P-2448	J-3181	J-2939	1600	5.6	209185.37	1.20	130	0.68
P-2884	J-1137	J-901	250	5.6	8881.60	2.09	130	16.44
P-2957	J-1138	J-805	250	7.8	11414.18	2.69	110	35.64
P-145	J-1139	J-1140	300	5.7	0.00	0.00	130	0.00
P-668	J-1143	J-479	250	5.7	857.83	0.20	130	0.22
P-2485	J-976	J-1144	450	5.7	17957.12	1.31	110	4.71
P-1377	J-1145	J-1146	300	5.7	3009.83	0.49	130	0.91
P-1283	J-319	J-320	300	5.7	3354.47	0.55	130	1.11
P-3042	J-1348	J-724	400	5.7	63078.26	5.81	130	62.85
P-1054	J-1150	J-1151	250	6.6	1262.87	0.30	110	0.60
P-1096	J-1150	J-1151	250	5.8	1356.91	0.32	110	0.69
P-1784	J-1138	J-663	800	5.8	37249.17	0.86	110	1.10
P-1144	J-1155	J-1156	250	5.8	1477.98	0.35	110	0.81

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-502	J-1159	J-441	250	5.8	0.00	0.00	130	0.00
P-1240	J-1160	J-1161	250	5.8	1692.34	0.40	110	1.04
P-58_SPL2	J21562	J-2802	300	5.9	0.00	0.00	130	0.00
P-1703	J-505	J-1162	500	5.9	10650.24	0.63	110	1.07
P-404	J-1163	J-565	300	5.9	0.00	0.00	130	0.00
P-119	J-796	J-1115	400	6.8	0.00	0.00	130	0.00
P-1859_SPL2	J48182	J48183	500	5.9	16626.61	0.98	130	1.79
P50393	J51495	J51493	250	11.1	0.00	0.00	130	0.00
P-325	J-1171	J-1172	300	6.0	0.00	0.00	130	0.00
P-130	J-739	J-1173	300	6.0	0.00	0.00	110	0.00
P-2057	J-1176	J-1177	1000	6.0	60338.71	0.89	130	0.67
P-2785	J-637	J-1045	300	6.0	12640.72	2.07	110	17.72
P-3013	J-945	J-715	250	6.0	13711.63	3.23	110	50.06
P-2773	J-3180	J-41(2)	1600	6.1	249875.67	1.44	130	0.94
P-1865	J-387	J-454	300	6.1	5750.09	0.94	130	3.02
P-343	J-1186	J-1187	250	6.1	0.00	0.00	110	0.00
P-57	J-1154	J-770	500	6.1	0.00	0.00	130	0.00
P-1824	J-1188	J-1189	300	6.1	4542.48	0.74	110	2.66
P-2570	J-1190	J-609	250	7.4	6252.80	1.47	110	11.69
P33970_SPL1	J36693	J36702	600	6.1	29964.00	1.23	130	2.20
P-1016	J-1191	J-1192	300	6.1	1684.03	0.28	130	0.31
P-2903	J-2913	J-1638	400	6.2	5868.01	0.54	130	0.77
P-2071	J-524	J-1353	300	6.2	5188.80	0.85	130	2.50
P-2757	J-1195	J-99	300	6.2	0.00	0.00	130	0.00
P-1336	J-1196	J-1197	300	6.2	2169.18	0.36	110	0.68
P-497	J-1198	J-1199	250	6.2	0.00	0.00	130	0.00
P-673	J-949	J-950	250	6.2	0.00	0.00	130	0.00
P-135	J-281	J-1178	400	6.2	0.00	0.00	130	0.00
P-2866	J-1179	J-1180	250	6.2	10013.04	2.36	130	20.52
P-2504	J-443	J-446	800	6.3	0.00	0.00	130	0.00
P-169	J-1206	J-1207	300	6.3	0.00	0.00	130	0.00
P-666	J-1117	J-1118	250	6.3	1921.19	0.45	130	0.97
P-585	J-1210	J-1211	250	6.3	0.00	0.00	130	0.00
P-3000_SPL1	J-983	J48181	300	6.4	22451.20	3.68	130	37.67
P-24	J-1220	J-1023	800	6.4	0.00	0.00	110	0.00
P-2857	J-3088	J-681	400	6.4	25200.04	2.32	130	11.49
P-2201	J-1222	J-466	300	9.0	15654.35	2.56	130	19.32
P-2102	J-869	J-1573	1000	6.4	62365.73	0.92	130	0.71
P-338	J-1223	J-1224	250	6.4	0.00	0.00	110	0.00
P-255	J-1227	J-1228	300	6.4	0.00	0.00	110	0.00
P-951	J-1230	J-1231	300	6.4	1741.23	0.29	110	0.45
P-875	J-1032	J-1033	250	10.4	0.00	0.00	130	0.00
P-1199	J-1032	J-1033	300	6.5	2685.45	0.44	130	0.74

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-344	J-1229	J-20	250	6.5	0.00	0.00	130	0.00
P-1730	J-801	J-1238	300	6.5	3741.52	0.61	110	1.86
P-1289	J-1700	J-1701	400	10.7	0.00	0.00	130	0.00
P-1566	J-1700	J-1701	400	6.5	10088.01	0.93	130	2.11
P-2216	J-3117	J-3164	500	6.5	16758.41	0.99	130	1.82
P-422	J-1241	J-1242	300	6.5	0.00	0.00	130	0.00
P-2139	J-808	J-720	500	6.5	12885.51	0.76	130	1.12
P-2958	J-806	J-1243	250	9.2	11414.18	2.69	110	35.64
P-1337	J-1015	J-1247	300	6.6	2169.18	0.36	110	0.68
P-2315	J-1248	J-1249	400	6.6	955.99	0.09	130	0.03
P-2909	J-2	J-1001	1000	6.7	153042.18	2.26	130	3.74
P-2982	J-1250	J-1251	250	8.7	14067.95	3.32	110	52.49
P-83	J-1252	J-1253	300	6.7	0.00	0.00	110	0.00
P-3051	ChrangChamresWT	J-826	400	6.7	41660.39	3.84	130	29.15
P-1338	J-1261	J-1262	300	6.8	2169.18	0.36	110	0.68
P-828	J-1263	J-1264	300	6.8	1200.23	0.20	130	0.17
P21570	J21569	J21570	300	6.8	0.00	0.00	130	0.00
P-1843	J-1284	J-1050	250	6.8	2651.62	0.63	130	1.75
P-1072	J-1267	J-1268	300	6.8	1751.59	0.29	110	0.46
P-474	J-1149	J-550	250	6.8	0.00	0.00	130	0.00
P-1339	J-1273	J-1274	300	6.8	2169.18	0.36	110	0.68
P-2863	J-721	J-1275	250	8.1	9901.18	2.33	110	27.39
P-1145	J-106	J-559	250	6.9	1477.98	0.35	110	0.81
P-1340	J-997	J-1276	300	6.9	2169.18	0.36	110	0.68
P21565	J21564	J21562	300	6.9	0.00	0.00	130	0.00
P-1341	J-1279	J-1273	300	6.9	2169.18	0.36	110	0.68
P-2260	J-2933	J-2934	400	23.1	10442.53	0.96	130	2.25
P-2383	J-1349	J-1350	800	8.1	50227.99	1.16	130	1.41
P-1804	J-1351	J-1352	250	7.0	3680.00	0.87	130	3.21
P21564	J21563	J21564	300	7.0	10060.80	1.65	130	8.52
P-1146	J-1282	J-1283	250	7.0	1477.98	0.35	110	0.81
P-939	J-1285	J-1286	250	7.0	1251.63	0.30	110	0.59
P31286	J-1969	J31286	225	7.0	6608.00	1.92	130	15.88
P-236	J-1287	J-1288	250	7.0	0.00	0.00	110	0.00
P-922	J-700	J-701	250	7.0	1937.00	0.46	130	0.98
P-655	J-224	J-1289	250	7.1	0.00	0.00	130	0.00
P-952	J-1291	J-1292	300	7.1	1741.23	0.29	110	0.45
P-1342	J-1293	J-1261	300	7.1	2169.18	0.36	110	0.68
P-100	J-1295	J-1296	300	7.1	0.00	0.00	110	0.00
P-894	J-825	J-755	400	7.2	33258.58	3.06	130	19.21
P-205	J-1302	J-911	300	7.2	0.00	0.00	110	0.00
P-2501	J-562	J-879	500	7.2	44163.20	2.60	130	10.95
P-2132	J-562	J-879	500	13.1	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P21550	J-1992	J21550	300	7.3	18288.01	2.99	130	25.77
56876	J41843	J41841	300	7.3	5857.71	0.96	130	3.13
P-1912	J-2924	J-3088	800	7.3	32244.84	0.74	130	0.62
P-1801	J-3158	J-3159	300	7.3	4068.80	0.67	130	1.59
P-232	J-1304	J-1305	250	7.3	0.00	0.00	110	0.00
P-514	J-936	J-1073	250	7.3	0.00	0.00	130	0.00
P-2464	J-815	J-1245	800	7.3	63205.95	1.46	130	2.16
P-1147	J-1308	J-1309	250	7.3	1477.98	0.35	110	0.81
P-1343	J-884	J-149	300	7.3	2169.18	0.36	110	0.68
P-1563	J-483	J-484	400	7.4	11345.81	1.04	130	2.62
P-483	J-1310	J-1311	250	7.4	0.00	0.00	130	0.00
P-2867	J-1313	J-1314	250	7.4	10013.04	2.36	130	20.52
P-261	J-1008	J-1009	300	7.4	0.00	0.00	130	0.00
P21561	J-3074	J21560	300	1.7	5272.00	0.86	130	2.57
P-3014	J-893	J-944	250	7.4	13711.63	3.23	110	50.06
P-1705	J-858	J-504	500	7.4	10650.24	0.63	110	1.07
P-1910	J-1221	J-17	800	7.5	36486.66	0.84	130	0.78
P-2047	J-788	J-2797	250	8.6	3052.89	0.72	130	2.27
P-1066	J-1218	J-1219	300	7.6	1751.59	0.29	130	0.33
P-2637	J-620	J-402	300	7.6	9590.73	1.57	130	7.80
P-2129	J-710	J-1320	900	7.6	56744.32	1.03	130	1.00
P-2967	J-1116	J-1202	500	7.7	52888.88	3.12	130	15.30
P-1200	J-373	J-1480	500	7.7	6978.20	0.41	130	0.36
P-2761	J-664	J-745	250	7.7	9034.87	2.13	110	23.12
P36705	J36703	J36705	225	9.9	0.00	0.00	130	0.00
P-2514	J-1438	J-1439	1600	7.8	210846.28	1.21	130	0.69
P-1509	J-1164	J-1165	300	7.8	2685.45	0.44	130	0.74
P-1896	J-1323	J-1324	250	7.8	3213.43	0.76	110	3.41
P-518	J-1325	J-461	250	7.8	0.00	0.00	130	0.00
P-1344	J-1326	J-1327	300	7.8	2169.18	0.36	110	0.68
P-2841	J-1107	J-1004	400	7.8	30941.38	2.85	130	16.80
P-505	J-1203	J-1204	250	8.2	0.00	0.00	130	0.00
P-2569	J-74	J-1303	250	7.9	6028.80	1.42	130	8.02
P-22	J-605	J-1329	800	7.9	0.00	0.00	110	0.00
P-2650	J-1459	J-1656	300	8.0	8538.92	1.40	130	6.29
P-25	J-604	J-1332	800	8.0	0.00	0.00	110	0.00
P-359	J-358	J-1333	250	9.8	0.00	0.00	130	0.00
P-544	J-268	J-269	250	8.0	0.00	0.00	130	0.00
P-2521	J-1335	J-1336	1200	8.0	108998.13	1.12	130	0.82
P-2804	J-875	J-1065	300	8.1	12704.18	2.08	130	13.12
P-1962	J-1339	J-1340	300	8.1	4755.19	0.78	130	2.13
P-2387	J-290	J-483	400	8.1	13674.45	1.26	130	3.70
P-1345	J-1342	J-1196	300	8.2	2169.18	0.36	110	0.68

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-658	J-949	J-1328	250	10.3	0.00	0.00	130	0.00
P-1505	J-1476	J-1164	300	8.2	2685.45	0.44	130	0.74
P-330	J-460	J-1343	250	9.0	0.00	0.00	130	0.00
P-2324_SPL1	J-481	J51502	300	11.2	5317.46	0.87	130	2.62
P-389_SPL4	J51511	J-1593	300	8.2	0.00	0.00	130	0.00
P-622	J-1493	J-725	250	8.2	3955.18	0.93	130	3.67
P-1484	J-1346	J-1347	300	10.9	4366.73	0.72	130	1.82
P-2996	J-1239	J-1240	400	8.2	36637.68	3.37	130	22.98
P-484	J-1164	J-912	250	8.2	0.00	0.00	130	0.00
P-601	J-415	J-1835	250	8.3	0.00	0.00	130	0.00
P-1880	J-1354	J-1355	300	8.7	4948.92	0.81	130	2.29
P-1261	J-1356	J-59	250	8.4	1675.42	0.40	130	0.75
P-1223	J-1357	J-1358	250	8.4	1741.24	0.41	110	1.10
P-125_SPL1	J-918	J21548	300	8.4	10174.39	1.67	130	8.70
P-133	J-959	J-960	400	8.5	0.00	0.00	130	0.00
P-1728	J-284	J-1878	500	8.5	14016.09	0.83	130	1.31
P-2585	J-1361	J-1362	400	8.5	12216.60	1.13	130	3.01
P-2943	J-1363	J-811	300	11.1	0.00	0.00	130	0.00
P-2983	J-1364	J-882	250	12.0	14067.95	3.32	110	52.49
P-2571	J-610	J-97	250	11.1	6252.80	1.47	110	11.69
P-2672	J-1418	J-1145	300	8.5	10090.99	1.65	130	8.57
P-323	J-1365	J-1366	250	8.5	0.00	0.00	110	0.00
P-1802	J-1299	J-1300	250	8.6	3680.00	0.87	130	3.22
P-1346	J-1367	J-1368	300	8.6	2169.18	0.36	110	0.68
P-2207	J-1215	J-561	500	9.2	12012.80	0.71	130	0.98
P-2730	J-1370	J-1051	250	8.6	7376.00	1.74	130	11.65
P-661	J-93	J-94	250	8.6	0.00	0.00	130	0.00
P-360	J-1373	J-358	250	10.0	0.00	0.00	130	0.00
P-851	J-1374	J-1375	600	11.6	0.00	0.00	130	0.00
P-1241	J-1378	J-1379	250	8.7	1692.34	0.40	110	1.04
P-1930	J-1200	J-1201	250	8.7	2789.95	0.66	130	1.93
P-1741	J-1701	J-1722	500	8.8	10088.01	0.59	130	0.71
P-311	J-1380	J-1381	250	8.8	0.00	0.00	110	0.00
P-1877	J-240	J-241	300	8.8	0.00	0.00	130	0.00
P-2488	J-1384	J-1176	800	8.8	60338.71	1.39	130	1.98
P-1073	J-670	J-1392	300	8.9	1751.59	0.29	110	0.46
P-904	J-1393	J-1394	250	8.9	244.27	0.06	110	0.03
P-98	J-1397	J-1398	400	10.1	0.00	0.00	130	0.00
P-1148	J-646	J-1399	250	8.9	1477.98	0.35	110	0.81
P-867	J-1137	J-1400	250	11.8	6.25	0.00	130	0.00
P-38	J-1401	J-1402	400	8.9	0.00	0.00	110	0.00
P-2811	J-1018	J-1104	250	8.9	8783.17	2.07	110	21.94
P-2956	J-361	J-1406	500	9.0	50931.90	3.00	130	14.26

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2199	J-3151	J-3144	1400	9.0	114504.61	0.86	130	0.42
P-1556_SPL2	J11169	J-1235	350	9.0	5870.92	0.71	130	1.48
P-1040	J-1631	J-1632	300	9.0	1344.88	0.22	130	0.21
P-2783	J-1375	J-780	300	9.1	10718.40	1.76	130	9.58
P-65	J-1413	J-1414	500	9.1	28833.00	1.70	130	4.97
P-905	J-1416	J-1417	250	9.1	244.27	0.06	110	0.03
P-2316	J-654	J-1248	400	9.1	955.99	0.09	130	0.03
P-906	J-1136	J-855	250	9.1	244.27	0.06	110	0.03
P-3035	J-27	J-629	300	9.5	26920.17	4.41	130	52.73
P-2972	J-3002	J-3003	300	11.6	10480.50	1.72	130	9.19
P-1897	J-1093	J-1323	250	9.2	3213.43	0.76	110	3.41
P-2780	J-1294	J-1240	400	12.1	15712.16	1.45	130	4.79
P-1041_SPL2	J21554	J21555	300	9.2	1344.88	0.22	130	0.20
P-2887	J-1493	J-1698	500	9.3	8560.72	0.50	130	0.52
P-907	J-1394	J-1416	250	9.3	244.27	0.06	110	0.03
P-2973	J-1421	J-44(1)	250	9.3	13219.20	3.12	110	46.78
P-1285	J-312	J-701	300	9.3	3137.23	0.51	130	0.98
P-1571_SPL2	J21553	J-1678	400	9.3	4143.68	0.38	130	0.41
P-1074	J-714	J-1127	300	10.2	1751.59	0.29	130	0.33
P-2593	J-1546	J-287	600	9.3	47612.26	1.95	130	5.18
P-15693	J22307	J22308	300	13.2	6081.61	1.00	130	3.35
P-2919_SPL2	J21549	J-3077	500	12.0	18846.40	1.11	130	2.26
P-1485	J-1423	J-1346	300	9.3	4366.73	0.72	130	1.82
P-396	J-1424	J-1425	300	9.4	2838.95	0.46	130	0.82
P-302	J-1426	J-1427	250	9.4	0.00	0.00	110	0.00
P-21	J-1428	J-1220	800	9.4	0.00	0.00	110	0.00
P-1347	J-1429	J-1430	300	9.4	2169.18	0.36	110	0.68
P-204	J-1431	J-1432	300	9.4	0.00	0.00	110	0.00
P-2988	J-464	J-1433	300	9.4	20614.40	3.38	110	43.83
P-953	J-1434	J-1435	300	9.4	1741.23	0.29	110	0.45
P-2020	J-1046	J-1440	1400	9.4	107546.73	0.81	110	0.51
P-2551	J-1441	J-1442	400	9.5	0.00	0.00	130	0.00
P-2613	J-1190	J-1449	900	9.5	83336.80	1.52	110	2.76
P-1348	J-1450	J-1326	300	9.5	2169.18	0.36	110	0.68
P-46	J-998	J-959	400	9.5	0.00	0.00	130	0.00
P-3036	J-586	J-328	250	12.7	19745.60	4.66	130	72.18
P-659	J-1452	J-1453	300	9.6	0.01	0.00	110	0.00
P-2966	J-1575	J-1576	300	9.6	18224.00	2.98	130	25.60
P-1349	J-1454	J-1455	300	9.6	2169.18	0.36	110	0.68
P-2042	J-3132	J-2911	1400	9.6	280080.01	2.11	130	2.22
P-2838	J-1645	J-2975	400	9.6	23222.98	2.14	130	9.88
P-2945_SPL1	J-2220	J50382	250	9.6	11852.79	2.79	130	28.05
P-1864	J-991	J-1347	250	9.7	4366.73	1.03	130	4.41

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-493	J-1387	J-1388	250	9.7	0.00	0.00	130	0.00
P-84	J-1460	J-1252	300	9.7	0.00	0.00	110	0.00
P-42	J-1461	J-1462	400	9.7	0.00	0.00	110	0.00
P-2990	J-375	J-1463	500	9.7	50861.06	3.00	130	14.23
P-1519	J-1325	J-427	500	9.7	6330.34	0.37	130	0.30
P-1224	J-1464	J-1465	250	9.7	1741.24	0.41	110	1.10
P-2896	J-1468	J-1469	400	9.7	28209.87	2.60	130	14.16
P-2984	J-883	J-1250	250	13.4	14067.95	3.32	110	52.49
P-2528	J-1466	J-1467	400	9.8	14742.39	1.36	130	4.26
P-541	J-1443	J-533	250	9.8	0.00	0.00	130	0.00
P-473	J-1447	J-1448	250	9.8	0.00	0.00	130	0.00
P-829	J-1471	J-1472	300	9.8	1200.23	0.20	130	0.17
P-1149	J-993	J-1473	250	9.8	1477.98	0.35	110	0.81
P-312	J-1474	J-1380	250	9.9	0.00	0.00	110	0.00
P-507	J-381	J-1415	250	9.9	0.00	0.00	130	0.00
P-2411	J-696	J-599	300	9.9	2127.80	0.35	110	0.65
P-3055	J-1475	J-951	400	9.9	81941.36	7.55	130	102.04
P-2394_SPL1	J-1066	J51509	400	10.0	12704.18	1.17	130	3.23
P-1350	J-1477	J-1429	300	10.0	2169.18	0.36	110	0.68
P-1805	J-1410	J-1411	250	10.0	3680.00	0.87	130	3.21
P-2769	J-490	J-491	300	10.0	10802.33	1.77	130	9.72
P-1662	J-1481	J-1482	250	10.2	392.21	0.09	110	0.07
P-1891	J-1483	J-1484	800	10.2	26407.25	0.61	110	0.58
P-97	J-1485	J-1486	400	10.3	0.00	0.00	130	0.00
P-187	J-1487	J-1488	300	10.3	0.00	0.00	130	0.00
P-2747	J-1489	J-539	1200	10.3	159108.72	1.63	130	1.65
P-2098	J-1492	J-835	300	10.4	7988.47	1.31	130	5.56
P-2224	J-653	J-122	300	13.6	6371.15	1.04	110	4.98
P-2881	J-2945	J-2946	600	10.4	59052.81	2.42	130	7.72
P51519	J51514	J51517	400	10.5	0.00	0.00	130	0.00
P-881	J-1495	J-1137	250	10.5	6.25	0.00	130	0.00
P-2640	J-1069	J-1479	500	10.6	40433.27	2.38	130	9.30
P-461	J-1337	J-1759	300	10.6	0.00	0.00	130	0.00
P-457	J-554	J-1345	250	10.6	0.00	0.00	130	0.00
P-1478	J-1498	J-1499	300	10.6	3219.22	0.53	110	1.41
P-1978	J-1500	J-1501	250	10.6	3225.65	0.76	110	3.43
P-582	J-1502	J-1503	250	10.6	1921.19	0.45	130	0.96
P-318	J-1504	J-1223	250	10.6	0.00	0.00	110	0.00
P-2127	J-274	J-310	250	10.6	9188.76	2.17	130	17.51
P-2796_SPL1	J-1331	J48174	400	12.9	26613.33	2.45	130	12.71
P-1150	J-1506	J-147	250	10.7	1477.98	0.35	110	0.81
P22944	J23343	J-2869	300	10.8	6836.85	1.12	130	4.17
P-2568_SPL4	J51505	J-74	250	10.9	6028.80	1.42	130	8.02

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-148	J-953	J-1508	300	14.4	0.00	0.00	110	0.00
P-1806	J-1411	J-1571	250	10.9	3680.00	0.87	130	3.22
P-2716	J-163	J-47	1400	10.9	216552.22	1.63	130	1.38
P-2869	J-1513	J-1514	250	11.0	10013.04	2.36	130	20.52
P-459	J-1515	J-1516	250	12.0	0.00	0.00	110	0.00
P-2938	J-1219	J-1665	250	12.3	11325.58	2.67	130	25.78
P-314	J-1187	J-81	250	11.1	0.00	0.00	110	0.00
P-2582	J-2949	J-2950	1200	11.1	130959.87	1.34	130	1.15
P-466	J-1518	J-1519	250	11.1	0.00	0.00	110	0.00
P-1944_SPL1	J-1598	J51500	250	13.3	2789.95	0.66	130	1.93
P-1963	J-1340	J-1520	300	11.1	4755.19	0.78	130	2.13
P-498	J-1503	J-1521	250	11.1	0.00	0.00	130	0.00
P-1064	J-712	J-1522	250	11.2	1323.27	0.31	110	0.66
P-921	J-1523	J-662	250	11.2	1200.23	0.28	130	0.40
P-1807	J-1299	J-1410	250	11.2	3680.00	0.87	130	3.22
P-1649	J-631	J-372	500	11.2	13732.56	0.81	130	1.26
P-2941	J-303	J-1437	250	11.2	11731.20	2.77	130	27.52
P-908	J-1526	J-1527	250	11.3	244.27	0.06	110	0.03
P-615	J-1528	J-1431	300	11.3	0.00	0.00	110	0.00
P-106	J-1529	J-1530	400	11.3	0.00	0.00	130	0.00
P-2118	J-1531	J-356	800	11.3	50568.14	1.16	130	1.43
P-331	J-1532	J-1533	250	11.3	0.00	0.00	110	0.00
P-3032	J-1547	J-1548	300	11.4	26881.48	4.40	130	52.59
P-2010	J-481	J-482	900	11.5	43803.20	0.80	130	0.62
P-2558	J-1535	J-970	1000	11.4	102956.00	1.52	110	2.45
P-27	J-1232	J-1412	600	11.4	13078.22	0.54	130	0.47
P-2947	J-1320	J-990	300	12.9	20113.92	3.29	130	30.73
P-2687	J-1047	J-1536	800	14.7	70405.58	1.62	130	2.63
P-822	J-1538	J-1539	400	11.5	1684.03	0.16	130	0.08
P-2758	J-1540	J-1195	300	11.5	0.00	0.00	130	0.00
P-1898	J-862	J-1542	250	11.5	3213.43	0.76	110	3.41
P-825	J-1053	J-25	450	15.0	406.88	0.03	110	0.00
P-2603	J-731	J-1543	400	13.3	15635.17	1.44	110	6.47
P-812	J-1544	J-273	300	11.6	1684.03	0.28	130	0.31
P-805	J-273	J-1544	300	13.4	0.00	0.00	130	0.00
P-3009	J-919	J-1545	250	11.6	16066.56	3.79	110	67.14
P-2221	J-2902	J-2887	1600	11.6	196815.75	1.13	130	0.60
P-371	J-1549	J-355	250	11.7	0.00	0.00	110	0.00
P-1881	J-1550	J-260	300	11.7	4948.92	0.81	130	2.29
P-336	J-1495	J-1552	250	11.8	0.00	0.00	130	0.00
P-2879_SPL1	J-1556	J48185	300	11.7	15038.40	2.46	130	17.94
P-1225	J-1553	J-1357	250	11.7	1741.24	0.41	110	1.10
P-47	J-1554	J-1555	400	11.7	0.00	0.00	110	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2298	J-1557	J-1558	400	11.8	11732.94	1.08	130	2.79
P-1899	J-121	J-1089	250	11.8	3213.43	0.76	110	3.41
P-2948	J-1566	J-1567	300	11.8	17252.79	2.82	130	23.13
P-580	J-911	J-2290	250	11.9	0.00	0.00	110	0.00
P-1305	J-752	J-757	250	12.8	1191.17	0.28	110	0.54
P-1005	J-694	J-1568	300	11.9	1684.03	0.28	130	0.31
P-1151	J-154	J-1506	250	12.0	1477.98	0.35	110	0.81
P-225	J-1414	J-2827	500	12.0	28833.00	1.70	130	4.97
P-415	J-2290	J-508	300	12.0	0.00	0.00	110	0.00
P-1152	J-1578	J-1579	250	12.0	1477.98	0.35	110	0.81
P-410	J-1569	J-1570	300	12.1	0.00	0.00	130	0.00
P-3053	J-79	J-1307	400	12.1	77639.18	7.15	130	92.34
P-954	J-1231	J-1580	300	12.1	1741.23	0.29	110	0.45
P-2870	J-1581	J-1582	250	12.2	10013.04	2.36	130	20.52
P-2979	J-1583	J-1406	500	12.3	60361.79	3.56	130	19.54
P-2890	J-1047	J-1584	800	12.3	91858.39	2.12	130	4.31
P-1226	J-1585	J-1586	250	12.4	1741.24	0.41	110	1.10
P-146	J-1587	J-1588	300	12.4	0.00	0.00	110	0.00
P-1774	J-1589	J-1590	300	12.4	6992.40	1.14	130	4.34
P-2936	J-1227	J-1042	300	12.5	18201.39	2.98	110	34.80
P-392	J-697	J-1296	300	12.5	0.00	0.00	110	0.00
50434	J-1594	J41931	300	12.5	5857.71	0.96	130	3.13
P-2465	J-1245	J-236	800	12.6	63205.95	1.46	130	2.16
P-955	J-1596	J-1597	300	12.6	1741.23	0.29	110	0.45
P-1931	J-2277	J-2607	250	12.6	2789.95	0.66	130	1.93
P-657	J-382	J-1818	250	12.7	0.00	0.00	130	0.00
P-2805	J-1174	J-1175	300	7.8	12769.60	2.09	130	13.25
P-1778	J-119	J-1599	300	12.7	3865.60	0.63	130	1.45
P-826	J-1600	J-1052	450	13.8	406.88	0.03	110	0.00
P-1692	J-1601	J-1602	250	12.8	2619.78	0.62	110	2.33
P-2144	J-1395	J-1396	250	12.8	2977.02	0.70	130	2.17
P-891	J-1543	J-1603	400	12.8	2625.58	0.24	110	0.24
P-29	J-1604	J-1100	500	12.8	0.00	0.00	130	0.00
P-1378	J-1068	J-680	300	12.8	3009.83	0.49	130	0.91
P-307	J-987	J-1366	250	12.9	0.00	0.00	110	0.00
P-2307	J-708	J-1084	500	12.9	18083.20	1.07	130	2.10
P-1738	J-1320	J-1605	900	13.0	36630.40	0.67	130	0.44
P-995	J-385	J-1606	250	13.0	1351.02	0.32	110	0.68
P-1825	J-1607	J-1608	300	13.0	4542.48	0.74	110	2.66
P-2317	J-1249	J-2913	400	13.0	955.99	0.09	130	0.03
P-2985_SPL1	J-1807	J48177	300	13.2	20326.40	3.33	130	31.34
P-956	J-1609	J-1434	300	13.0	1741.23	0.29	110	0.45
P-1826	J-1610	J-1611	300	13.0	4542.48	0.74	110	2.66

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2358	J-1612	J-1613	400	13.0	12289.07	1.13	110	4.14
P-2013	J-1616	J-492	900	13.1	41091.88	0.75	110	0.75
P-41	J-527	J-2942	400	13.1	24998.66	2.30	130	11.32
P-1530	J-1617	J-1618	250	13.1	1771.97	0.42	130	0.83
P-957	J-1619	J-1596	300	13.1	1741.23	0.29	110	0.45
P-361_SPL1	J-1277	J51497	250	13.2	12248.00	2.89	130	29.81
P-356	J-1492	J-137	300	13.3	0.00	0.00	130	0.00
P-821	J-1623	J-1529	400	13.3	1684.03	0.16	130	0.08
P-1351	J-1624	J-1625	300	13.3	2169.18	0.36	110	0.68
P-2126	J-931	J-133	250	3.6	9188.76	2.17	130	17.51
P-2795	J-938	J-1628	400	13.4	21566.32	1.99	130	8.61
P-1663	J-1025	J-1629	250	13.4	392.21	0.09	110	0.07
P-1709	J-1265	J-1703	300	13.4	1401.17	0.23	130	0.22
P-369	J-1081	J-1633	250	13.5	0.00	0.00	110	0.00
P22319	J22318	J22319	250	18.0	5184.00	1.22	130	6.06
P-2904	J-406	J-1638	400	13.5	5868.01	0.54	130	0.77
P-298	J-484	J-1310	250	13.5	0.00	0.00	130	0.00
P-2228	J-1214	J-1215	350	13.5	5870.92	0.71	130	1.48
P-2950	J-420	J-841	250	13.5	6090.23	1.44	130	8.17
P-2291_SPL2	J42473	J-859	500	13.6	17390.00	1.03	130	1.95
P-530	J-955	J-1203	250	13.6	0.00	0.00	130	0.00
P-504	J-1254	J-1312	250	14.1	0.00	0.00	130	0.00
P-970	J-1647	J-85	300	13.7	1692.34	0.28	110	0.43
P-909	J-1649	J-1650	250	13.8	244.27	0.06	110	0.03
P-2562	J-1651	J-442	800	13.8	3228.14	0.07	130	0.01
P-1510	J-1165	J-1652	300	13.9	2685.45	0.44	130	0.74
P-940	J-1653	J-1285	250	13.9	1251.63	0.30	110	0.59
P-1029	J-372	J-936	400	13.9	2651.62	0.24	130	0.18
P-1711	J-2039	J-2040	300	14.5	1692.80	0.28	130	0.31
P21566	J21564	J21565	300	17.3	0.00	0.00	130	0.00
P-2612	J-1654	J-1013	300	14.1	9415.08	1.54	110	10.27
P-1750	J-1315	J-1316	400	14.1	16876.80	1.55	130	5.47
P-737	J-1657	J-1658	300	14.1	0.01	0.00	130	0.00
P-1264	J-1655	J-1162	500	14.1	7551.15	0.45	110	0.57
P-1766	J-1965	J-3091	600	14.2	0.00	0.00	130	0.00
P-1153	J-1659	J-886	250	14.2	1477.98	0.35	110	0.81
P-1154	J-1283	J-1660	250	14.2	1477.98	0.35	110	0.81
P-355	J-550	J-1183	300	14.3	0.00	0.00	130	0.00
P-177	J-1661	J-1662	300	14.3	0.00	0.00	110	0.00
P-1306	J-1663	J-1535	250	14.3	1191.17	0.28	110	0.54
P-2971	J-1494	J-1048	400	14.4	7608.15	0.70	130	1.25
P-1132	J-584	J-851	300	14.4	1936.00	0.32	130	0.40
P-2643	J-1668	J-1669	800	14.4	64580.94	1.49	130	2.24

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-147	J-1670	J-1671	300	14.5	0.00	0.00	110	0.00
P-376	J42473	J-2964	250	14.5	0.00	0.00	130	0.00
P-71	J-1666	J-1667	400	14.6	0.00	0.00	130	0.00
P-656	J-480	J-531	250	15.2	857.83	0.20	130	0.22
P-2204	J-237	J-839	300	14.5	3205.13	0.52	130	1.02
P-2479	J-146	J-234	800	14.5	63205.95	1.46	130	2.16
P-1265	J-858	J-1655	500	14.6	7551.15	0.45	110	0.57
P-2681	J-432	J-433	300	14.6	9573.99	1.57	130	7.77
P-1836	J-1673	J-1674	600	15.8	16827.20	0.69	130	0.75
P-528	J-946	J-440	250	14.7	0.00	0.00	130	0.00
P-2662	J-1385	J-1386	250	14.8	6715.20	1.58	130	9.79
P-688	J-1681	J-1682	250	14.8	0.00	0.00	130	0.00
P-481	J-1337	J-1338	300	14.9	0.00	0.00	130	0.00
P-910	J-1650	J-1685	250	15.0	244.27	0.06	110	0.03
P-372	J-1686	J-1687	250	15.0	0.00	0.00	130	0.00
P-482	J-815	J-816	250	16.9	0.00	0.00	130	0.00
P-1900	J-1542	J-1688	250	15.2	3213.43	0.76	110	3.41
P-1886	J-1354	J-1689	300	15.2	4948.92	0.81	130	2.29
P-30	J-1690	J-1691	500	19.4	0.00	0.00	130	0.00
P-2993	J-1232	J-878	400	15.3	20677.92	1.90	130	7.97
P-476	J-1692	J-1693	250	15.3	0.00	0.00	110	0.00
P-1394	J-1334	J-700	250	15.4	1937.00	0.46	130	0.98
P-3048_SPL4	J50379	J-527	250	33.5	4806.15	1.13	130	5.27
P-2076	J-1940	J-1254	500	16.6	20534.51	1.21	130	2.65
P-1017	J-1696	J-1697	300	15.5	1684.03	0.28	130	0.31
P-571	J-1211	J-749	250	15.5	0.00	0.00	130	0.00
P-260	J-570	J-15	300	17.2	0.00	0.00	130	0.00
P-196	J-96	J-1702	300	15.9	0.00	0.00	130	0.00
P-1227	J-1465	J-1707	250	15.9	1741.24	0.41	110	1.10
P-1763	J-978	J-1708	800	16.0	45424.88	1.05	130	1.17
P-911	J-1709	J-1526	250	16.0	244.27	0.06	110	0.03
P-2234	J-1113	J-1114	500	16.0	13444.68	0.79	130	1.21
P-1125	J-1091	J-1710	300	16.1	1923.20	0.31	130	0.40
P-316	J-847	J-1337	250	16.1	0.00	0.00	130	0.00
P-535	J-1675	J-1676	250	16.1	0.00	0.00	130	0.00
P-1155	J-887	J-1308	250	16.1	1477.98	0.35	110	0.81
P-2678	J-404	J-1731	300	16.1	9918.40	1.62	130	8.30
P-500	J-1773	J-1774	250	16.2	2003.20	0.47	130	1.04
P-1731	J-1713	J-966	300	16.2	3741.52	0.61	110	1.86
P-2816	J-1509	J-1510	300	16.2	0.00	0.00	130	0.00
P-3022	J-2905	J-1803	250	16.2	21372.84	5.04	130	83.58
P-348	J-1717	J-1718	300	16.3	0.00	0.00	110	0.00
P-33	J-1719	J-1655	500	16.3	0.00	0.00	110	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-534	J-1785	J-1786	250	16.3	0.00	0.00	130	0.00
P-3038	J-1583	J-1523	250	16.3	21474.70	5.06	130	84.32
P-844	J-1724	J-1058	400	16.4	16222.52	1.49	130	5.08
P-2277	J-1726	J-1727	300	16.4	3478.07	0.57	130	1.19
P-2209	J-1162	J-1728	500	16.4	18201.39	1.07	110	2.89
P-2792	J-1756	J-2	1600	21.2	307712.45	1.77	130	1.38
P-380	J-897	J-1664	250	16.5	212.61	0.05	130	0.02
P-496	J-538	J-1729	250	16.6	0.00	0.00	130	0.00
P-2911	J-1730	J-830	300	19.0	15249.32	2.50	110	25.08
P-654	J-342	J-388	250	16.6	0.00	0.00	130	0.00
P-1270	J-318	J-1732	250	20.7	1815.14	0.43	110	1.18
P-1772	J-1733	J-1734	400	16.7	6835.19	0.63	130	1.03
P-2174	J-1735	J-26	450	20.0	13384.92	0.97	110	2.73
P-1228	J-1736	J-1585	250	16.8	1741.24	0.41	110	1.10
P-2676	J-1769	J-1639	500	16.8	28135.87	1.66	130	4.75
P-1693	J-1602	J-1737	250	16.9	2619.78	0.62	110	2.33
P-1382	J-1738	J-1739	500	16.9	7816.01	0.46	130	0.44
P-1694	J-1740	J-1741	250	16.9	2619.78	0.62	110	2.33
P-379	J-1743	J-1744	250	16.9	0.00	0.00	130	0.00
P14545	J16741	J16737	600	17.6	15184.00	0.62	130	0.62
P-912	J-850	J-1135	250	17.0	244.27	0.06	110	0.03
P-2599	J-1678	J-181	300	17.4	5966.59	0.98	130	3.24
P21552	J21551	J-2112	400	17.1	16548.95	1.52	130	5.27
P-1695	J-1745	J-1746	250	17.1	2619.78	0.62	110	2.33
P-996	J-1749	J-1606	250	17.1	1351.02	0.32	110	0.68
P-1028	J-467	J-158	300	17.2	8049.55	1.32	130	5.64
P-626	J-1750	J-1751	250	17.2	1921.19	0.45	130	0.96
P-387	J-1019	J-1668	300	17.2	0.00	0.00	130	0.00
P-2522	J-1753	J-1335	1200	17.2	108998.13	1.12	130	0.82
P-2128	J-1101	J-931	250	11.4	9188.76	2.17	130	17.51
P-341	J-1343	J-502	250	18.0	0.00	0.00	130	0.00
P-183	J-1425	J-1758	300	17.4	2838.95	0.46	130	0.82
P-1504	J-567	J-568	300	17.4	2685.45	0.44	130	0.74
P-429	J-999	J-1704	300	17.5	0.00	0.00	130	0.00
P-958	J-1762	J-1763	300	17.5	1741.23	0.29	110	0.45
P-2359	J-1760	J-1761	400	17.5	12289.07	1.13	110	4.14
P-818	J-770	J-771	500	17.6	0.00	0.00	130	0.00
P-570	J-1765	J-505	250	17.6	0.00	0.00	110	0.00
P-346_SPL1	J-1804	J51507	250	17.7	7816.01	1.84	130	12.97
P21560_SPL2	J50384	J-2113	200	22.8	1102.39	0.41	130	1.02
P-1229	J-1770	J-1132	250	17.8	1741.24	0.41	110	1.10
P-1970	J-1100	J-1771	500	17.8	0.00	0.00	130	0.00
P-309	J-1432	J-1587	300	17.9	0.00	0.00	110	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-799	J-1623	J-1772	250	17.9	556.13	0.13	130	0.10
P-1901	J-1775	J-1776	250	17.9	3213.43	0.76	110	3.41
P-1156	J-560	J-1777	250	17.9	1477.98	0.35	110	0.81
P-1006	J-1538	J-272	300	18.0	1684.03	0.28	130	0.31
P-800	J-1557	J-266	250	18.0	556.13	0.13	130	0.10
P-176	J-1056	J-1782	300	18.0	0.00	0.00	130	0.00
P-2706	J-1783	J-1097	250	18.0	2127.80	0.50	110	1.59
P-1892	J-1483	J-893	800	18.0	26407.25	0.61	110	0.58
P-2628	J-3167	J-3168	300	18.1	9323.20	1.53	130	7.40
P-1739	J-1778	J-1779	500	18.1	10088.01	0.59	130	0.71
P-2682	J-433	J-1219	300	19.2	9573.99	1.57	130	7.77
P-4	J-1784	J-442	300	20.5	3228.14	0.53	130	1.04
P-3033	J-592	J-1547	300	18.2	26881.48	4.40	130	52.59
P-780	J-443	J-1374	800	18.3	0.00	0.00	130	0.00
P-53	J-960	J-1869	400	18.3	0.00	0.00	130	0.00
P-377	J-1780	J-1781	250	18.3	0.00	0.00	130	0.00
P-1018	J-1788	J-809	300	18.4	1684.03	0.28	130	0.31
P-2360	J-1761	J-1613	400	18.4	12289.07	1.13	110	4.14
P-2825	J-561	J-562	500	18.5	44163.20	2.60	130	10.95
P-1495	J-439	J-1534	300	18.5	4117.18	0.67	130	1.63
P-495	J-65	J-96	300	18.5	0.00	0.00	130	0.00
P-2661	J-525	J-1232	600	20.3	33756.15	1.38	130	2.74
P-1427	J-936	J-1284	300	18.6	2651.62	0.43	130	0.72
P-201	J-1789	J-1790	300	18.6	0.00	0.00	130	0.00
P-928	J-318	J-892	400	23.1	2235.03	0.21	110	0.18
P-576	J-1791	J-1792	250	18.6	978.66	0.23	130	0.28
P31289	J-1316	J31288	225	20.6	4998.79	1.46	130	9.47
P31288	J-1316	J31288	225	18.6	5270.01	1.53	130	10.44
P-2710	J-1599	J-1793	400	18.7	16827.97	1.55	130	5.44
P-2190	J-1795	J-953	300	18.9	3650.16	0.60	110	1.78
P-2701	J-1796	J-1690	800	18.9	72020.95	1.66	130	2.75
P-618	J-1799	J-1800	250	19.1	0.00	0.00	130	0.00
P-2939	J-2975	J-2976	400	19.1	29944.00	2.76	130	15.82
P-354	J-1705	J-1706	250	19.2	0.00	0.00	130	0.00
P-590	J-1787	J-665	300	19.2	1921.19	0.31	130	0.40
P-2844	J-1801	J-1802	700	19.3	75566.25	2.27	110	7.84
P-1987	J-1677	J-1678	300	19.3	3099.34	0.51	130	0.96
P-988	J-1806	J-985	250	19.4	1276.65	0.30	110	0.62
P-15690	J21768	J21852	250	19.5	2966.40	0.70	130	2.16
P-2442	J-67	J-2429	300	19.6	7502.40	1.23	130	4.95
P22323	J-1057	J22321	400	19.6	16222.52	1.49	130	5.08
P-959	J-1813	J-1814	300	19.7	1741.23	0.29	110	0.45
P-2826	J-879	J-1556	500	19.7	44163.20	2.60	130	10.95

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2845	J-1816	J-1817	700	20.8	75566.25	2.27	110	7.84
P-1988	J-1809	J-1810	300	19.8	3099.34	0.51	130	0.96
P-941	J-1820	J-1653	250	19.8	1251.63	0.30	110	0.59
P-2489	J-1797	J-613	800	23.6	60338.71	1.39	130	1.98
P51537	J-2959	J-2960	500	20.0	0.00	0.00	130	0.00
P-2486	J-975	J-473	450	20.3	17957.12	1.31	110	4.71
P-1320	J-1822	J-1823	250	20.0	1902.63	0.45	110	1.29
P-2959	J-1825	J-1243	250	20.2	12392.84	2.92	110	41.51
P-1688	J-1098	J-1826	1200	20.2	34865.76	0.36	130	0.10
P-1714	J-297	J-1827	300	20.2	4210.88	0.69	130	1.70
P-2994	J-26	J-1059	250	20.3	15714.22	3.71	110	64.43
P-1817	J-2888	J-301	1000	20.3	63442.94	0.93	130	0.73
P-1352	J-1828	J-1829	300	20.3	2169.18	0.36	110	0.68
P-2003	J-1157	J-1158	300	20.3	4392.42	0.72	130	1.84
P-830	J-1830	J-1471	300	20.3	1200.23	0.20	130	0.17
P-1157	J-1660	J-1155	250	20.3	1477.98	0.35	110	0.81
P-2385_SPL1	J-3147	J22318	600	20.4	26783.51	1.10	130	1.78
P-2989	J-1834	J-463	300	20.4	20614.40	3.38	110	43.83
P-1390	J-30	J-69	600	20.5	29964.00	1.23	130	2.20
P-2823	J-1836	J-1837	1400	20.6	307712.45	2.31	130	2.65
P-2137	J-535	J-1803	400	20.6	9520.65	0.88	130	1.89
P-3020	J-1838	J-591	300	20.7	24945.48	4.08	130	45.79
P-347	J-1839	J-1198	250	20.7	0.00	0.00	130	0.00
P-1496	J-1033	J-1534	300	20.8	2685.45	0.44	130	0.74
P-2714	J-1840	J-843	500	20.8	14012.80	0.83	130	1.31
P-1275	J-1841	J-1842	300	21.3	3454.93	0.57	130	1.18
P-1822	J-1843	J-517	300	21.0	4152.00	0.68	130	1.65
P-792	J-717	J-1844	800	21.0	1850.86	0.04	130	0.00
P-2733_SPL1	J-1694	J50381	250	21.1	7571.20	1.79	130	12.23
P11175	J11174	J11175	250	13.2	0.00	0.00	130	0.00
P22941	J-420	J-977	250	22.0	6000.97	1.41	130	7.95
P-198	J-1831	J-1832	300	21.6	0.00	0.00	130	0.00
P-1983	J-1847	J-1848	800	21.7	36630.40	0.84	130	0.78
P-596	J-551	J-1271	300	21.7	0.00	0.00	130	0.00
P-2821	J-683	J-1449	300	21.7	13234.18	2.17	110	19.29
P-2951	J-1850	J-1654	250	21.7	12572.80	2.96	110	42.63
P-2707	J-1783	J-695	250	21.8	2127.80	0.50	110	1.59
P-2471	J-2834	J-767	600	23.8	36355.11	1.49	130	3.14
P-892	J-1648	J-367	500	22.3	6592.00	0.39	130	0.32
P-1732	J-1856	J-1713	300	22.0	3741.52	0.61	110	1.86
P-1960	J-677	J-742	300	22.0	4755.20	0.78	130	2.13
P-1652	J-1857	J-1858	250	22.0	3620.35	0.85	110	4.25
P-1918	J-1446	J-1909	600	30.1	17390.00	0.71	130	0.80

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2374	J-316	J-1859	300	22.1	6836.85	1.12	130	4.17
P-2934	J-3194	J-3195	400	22.2	29673.60	2.73	130	15.55
P-2044	J-1860	J-1861	250	22.2	3052.89	0.72	130	2.27
P-1353	J-1862	J-1624	300	22.2	2169.18	0.36	110	0.68
P-1019	J-1131	J-810	300	22.2	1684.03	0.28	130	0.31
P-1984	J-1605	J-1864	800	22.9	36630.40	0.84	130	0.78
P-1402	J-1865	J-131	250	22.4	2049.19	0.48	110	1.48
P-2842	J-401	J-1645	400	22.6	30941.38	2.85	130	16.80
P-40	J-1866	J-1413	500	22.6	28833.00	1.70	130	4.97
P-1653	J-1867	J-1868	250	22.6	3620.35	0.85	130	3.12
P16764	J16596	J-2812	600	22.7	24803.23	1.02	130	1.55
P-321	J-1194	J-1923	250	22.8	0.00	0.00	130	0.00
P-2264	J-1872	J-1873	300	22.9	3478.07	0.57	110	1.62
P-2072	J-1815	J-523	300	22.9	5188.80	0.85	130	2.50
P-927	J-28	J-1114	1000	22.9	13444.68	0.20	130	0.04
P-2644	J-2907	J-1669	800	23.0	64580.94	1.49	130	2.24
P-391	J-1877	J-623	300	23.0	0.00	0.00	110	0.00
P-1255	J-64947	J-1222	600	36.9	20700.75	0.85	130	1.11
P-471	J-61	J-1821	400	23.2	0.00	0.00	130	0.00
P-1844	J-1167	J-1863	250	23.2	2651.62	0.63	130	1.75
P-1158	J-1879	J-1813	250	23.3	1477.98	0.35	110	0.81
P-394	J-1895	J-569	300	23.4	0.00	0.00	130	0.00
P-1354	J-1880	J-1828	300	23.4	2169.18	0.36	110	0.68
P-606	J-531	J-529	250	23.5	857.83	0.20	130	0.22
P-384	J-1400	J-1882	250	28.6	0.00	0.00	130	0.00
P-1551	J-1874	J-1875	250	25.4	1771.98	0.42	130	0.83
P-676	J-1883	J-1884	300	23.6	0.00	0.00	130	0.00
P-2586	J-1886	J-1361	400	23.6	12216.60	1.13	130	3.01
P-726	J-1887	J-800	450	23.7	297.91	0.02	110	0.00
P-1403	J-1888	J-1074	250	23.7	2049.19	0.48	110	1.48
P-931	J-201	J-21	250	23.8	1222.60	0.29	110	0.57
P-157	J-1890	J-1227	450	23.8	0.00	0.00	110	0.00
P-724	J-185	J-732	250	23.8	29.04	0.01	110	0.00
P-546	J-1891	J-1892	300	23.8	1089.39	0.18	130	0.14
P-2846	J-1816	J-518	700	23.9	75566.25	2.27	110	7.84
P-653	J-139	J-33	300	24.1	0.01	0.00	110	0.00
P-1479	J-1901	J-1813	300	24.1	3219.22	0.53	110	1.41
P-1867	J-1255	J-1233	300	27.7	5750.09	0.94	130	3.02
P-2806	J-50(2)	J-1101	250	13.2	1592.03	0.38	130	0.68
P-1845	J-1902	J-1903	250	24.3	2651.62	0.63	130	1.75
P-1890	J-301	J-1331	1000	24.3	50081.24	0.74	130	0.47
P-1276	J-675	J-1842	300	24.3	3454.93	0.57	130	1.18
P-2987	J-1024	J-1026	1250	24.3	361106.19	3.41	110	8.43

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1789	J-1025	J-1904	250	24.4	1822.28	0.43	110	1.19
P-1159	J-1905	J-1282	250	24.4	1477.98	0.35	110	0.81
P-2847	J-692	J-1906	700	29.9	75566.25	2.27	110	7.84
P-39	J-1907	J-1908	400	24.5	0.00	0.00	130	0.00
P-525	J-1793	J-1080	250	24.5	0.00	0.00	130	0.00
P-436	J-1976	J-1977	250	24.5	0.00	0.00	130	0.00
P-1902	J-1090	J-1910	250	24.6	3213.43	0.76	110	3.41
P-2639	J-3181	J-3182	300	27.8	9590.73	1.57	130	7.80
P-1715	J-1778	J-952	900	24.7	33715.19	0.61	130	0.38
P-1827	J-1608	J-1912	300	24.8	4542.48	0.74	110	2.66
P-362	J-1913	J-1914	250	24.8	0.00	0.00	110	0.00
P-2364	J-2718	J-2981	500	25.3	18683.21	1.10	130	2.23
P-1160	J-1916	J-1879	250	25.3	1477.98	0.35	110	0.81
P-296	J-155	J-157	250	26.9	0.00	0.00	130	0.00
P-971	J-1917	J-1918	300	25.4	1692.34	0.28	110	0.43
P-2696	J-217	J-291	1600	25.4	307712.45	1.77	130	1.38
P-2038	J-2979	J-2970	500	25.5	13852.80	0.82	130	1.28
P-2968	J-1202	J-1922	500	25.6	52888.88	3.12	130	15.30
P-328	J-1882	J-1921	250	25.8	0.00	0.00	130	0.00
P-1862_SPL1	J-1764	J48184	500	25.7	16626.61	0.98	130	1.79
P-2449	J-1926	J-1927	600	25.8	6414.63	0.26	130	0.13
P-207	J-1928	J-1929	300	25.8	0.00	0.00	130	0.00
P-2793	J-1930	J-684	1600	26.0	307712.45	1.77	130	1.38
P-293	J-1931	J-1932	250	26.0	0.00	0.00	110	0.00
P-1989	J-1933	J-1934	300	26.1	3099.34	0.51	130	0.96
P-1920	J-1853	J-750	250	27.2	0.00	0.00	130	0.00
P-942	J-1935	J-1936	250	26.2	1251.63	0.30	110	0.59
P-943	J-1937	J-84	250	26.3	1251.63	0.30	110	0.59
P-1230	J-1532	J-1938	250	26.4	1741.24	0.41	110	1.10
P-2239	J-1943	J-512	1000	26.5	76477.12	1.13	110	1.41
P-1903	J-1910	J-1092	250	26.5	3213.43	0.76	110	3.41
P-1629	J-1730	J-556	250	26.5	2528.28	0.60	110	2.19
P-2691	J-1952	J-1953	300	26.7	8538.93	1.40	130	6.29
P-1486	J-1945	J-1946	300	26.7	4366.73	0.72	110	2.47
P-1718	J-1948	J-1949	1000	26.9	34418.30	0.51	130	0.24
P-2704	J-3141	J-3142	300	26.9	10424.00	1.71	130	9.10
P-1719	J-1950	J-1951	1000	26.9	34418.30	0.51	130	0.24
P-2242	J-2980	J-3184	300	27.1	6198.40	1.01	130	3.47
P-433_SPL1	J-1645	J48176	250	27.2	7718.40	1.82	130	12.67
P-486	J-1954	J-1354	250	27.3	0.00	0.00	130	0.00
P-2974	J-1438	J-561	500	28.5	56176.00	3.31	130	17.10
P-492	J-1958	J-1931	250	27.4	0.00	0.00	110	0.00
P-1904	J-1959	J-1532	250	27.5	3213.43	0.76	110	3.41

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-795	J-2987	J-2988	250	27.5	537.60	0.13	130	0.09
P-2627	J-3165	J-3166	300	27.5	9323.20	1.53	130	7.40
P-1231	J-1960	J-910	250	27.5	1741.24	0.41	110	1.10
P-2412	J-1844	J-1836	800	27.6	0.00	0.00	130	0.00
P-997	J-1961	J-1962	250	27.7	1351.02	0.32	110	0.68
P-467	J-1380	J-1765	250	27.7	0.00	0.00	110	0.00
P-1487	J-1963	J-778	300	27.8	4366.73	0.72	130	1.82
P-960	J-922	J-910	300	27.8	1741.23	0.29	110	0.45
P-1654	J-1964	J-1857	250	27.8	3620.35	0.85	110	4.25
P-2954	J-1363	J-1540	300	28.1	3478.08	0.57	130	1.19
P22328	J-374	J-1509	250	28.6	1.65	0.00	130	0.00
P-2817	J-374	J-1509	300	28.0	1.65	0.00	130	0.00
P-2014	J-1545	J-1616	900	28.0	41091.88	0.75	110	0.75
P-2975	J-1024	J-1970	1250	28.3	342904.83	3.23	110	7.66
P-1232	J-1770	J-1973	250	28.4	1741.24	0.41	110	1.10
P-2529	J-3087	J-1979	400	30.8	14742.39	1.36	130	4.26
P-310	J-1974	J-1958	250	28.4	0.00	0.00	110	0.00
P-913	J-1543	J-1975	250	28.4	244.27	0.06	110	0.03
P-1355	J-885	J-1880	300	28.6	2169.18	0.36	110	0.68
P-1161	J-1578	J-220	250	30.6	1477.98	0.35	110	0.81
P-2688	J-1980	J-1909	800	30.3	70405.58	1.62	130	2.63
P-499	J-1981	J-914	250	29.2	1921.19	0.45	130	0.96
P-1524	J-3112	J-1632	300	34.6	2894.18	0.47	130	0.85
P-2922	J-1109	J-1984	1350	30.3	326498.94	2.64	110	4.81
P-327	J-791	J-821	250	29.4	0.00	0.00	110	0.00
P-2831	J-1985	J-1986	300	30.0	14311.89	2.34	130	16.36
P-234	J-1305	J-832	250	29.6	0.00	0.00	110	0.00
P-1007	J-1529	J-693	300	29.8	1684.03	0.28	130	0.31
P-233	J-948	J-1304	250	29.9	0.00	0.00	110	0.00
P-2113	J-1893	J-1894	300	30.0	5364.80	0.88	130	2.66
P-2963	J-1463	J-1724	500	31.1	35230.40	2.08	130	7.21
P-1020	J-1539	J-1696	300	30.2	1684.03	0.28	130	0.31
P-2666	J16467	J-3179	300	30.3	9763.20	1.60	130	8.06
P-2712	J-2907	J-1911	1000	30.4	116330.40	1.71	130	2.25
P-87	J-1994	J-1995	300	30.5	0.00	0.00	110	0.00
P-864	J-1999	J-2000	250	30.9	6.25	0.00	130	0.00
P-2655	J-3183	J-2873	300	31.1	9612.79	1.57	130	7.83
P-237	J-1288	J-947	250	31.1	0.00	0.00	110	0.00
P-1696	J-1737	J-1740	250	31.2	2619.78	0.62	110	2.33
P-1356	J-1327	J-1477	300	31.2	2169.18	0.36	110	0.68
P-2210	J-1728	J-1227	500	31.2	18701.39	1.07	110	2.89
P-63	J-2002	J-333	600	32.4	27953.57	1.14	130	1.93
P-2591	J-853	J-145	300	31.3	4757.21	0.78	130	2.13

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2736	J-1479	J-799	500	35.9	34731.23	2.05	130	7.02
P-345	J-753	J-1974	250	31.3	0.00	0.00	110	0.00
P-2937	J-1970	J-1109	1350	31.3	342904.83	2.77	110	5.26
P-2413	J-2019	J-1815	400	31.3	9955.75	0.92	130	2.06
P-2766_SPL1	J-2708	J22320	1400	31.4	251329.83	1.89	130	1.82
P-2478	J-234	J-815	800	31.6	63205.95	1.46	130	2.16
P-320	J-2005	J-293	300	31.7	0.00	0.00	130	0.00
P-1176	J-2006	J-2007	250	31.8	1472.19	0.35	110	0.80
P-1964	J-232	J-1339	300	31.8	4755.19	0.78	130	2.13
P-925	J-2992	J-2993	500	32.0	4163.19	0.25	130	0.14
P-1404	J-2010	J-1888	250	32.2	2049.19	0.48	110	1.48
P-235	J-822	J-1287	250	32.3	0.00	0.00	110	0.00
P-2557	J-3191	J-3192	300	32.4	8595.20	1.41	130	6.36
P-1162	J-148	J-1916	250	32.5	1477.98	0.35	110	0.81
P-1765	J-1362	J-2017	400	32.5	6715.20	0.62	130	0.99
P-373	J-1427	J-2018	250	32.5	0.00	0.00	110	0.00
P-1911	J-17	J-736	800	32.7	36486.66	0.84	130	0.78
P57098	J56920	J56923	250	32.7	0.00	0.00	130	0.00
P-2516	J-1556	J-1277	500	32.9	29124.79	1.72	130	5.07
P-2184	J-1558	J-2027	400	33.0	10605.05	0.98	130	2.31
P-1197	J-1603	J-2028	400	33.2	4097.77	0.38	110	0.54
P-2572	J-2030	J-1673	600	33.0	19803.20	0.81	130	1.02
P-2880	J-2996	J-2997	400	33.1	26190.40	2.41	130	12.34
P-2093	J-2031	J-1492	300	33.1	7988.47	1.31	130	5.56
P-2692	J-2048	J-1656	300	33.1	8538.93	1.40	130	6.29
P-2622	J-3036	J-3037	300	33.3	9289.60	1.52	130	7.35
P-93	J-323	J-580	300	33.9	0.00	0.00	110	0.00
P-2762	J-971	J-2032	1400	34.0	251329.83	1.89	130	1.82
P-438	J-2033	J-2034	300	35.3	0.00	0.00	130	0.00
P-2019	J-1889	J-3136	250	33.5	3376.00	0.80	130	2.74
P-332	J-2035	J-1039	250	33.6	0.00	0.00	110	0.00
P-1808	J-2001	J-1571	250	33.7	3680.00	0.87	130	3.21
P-2770_SPL1	J-719	J50387	300	33.7	10802.33	1.77	130	9.72
P-608	J-1967	J-1968	250	34.1	0.00	0.00	130	0.00
P-2555	J-41(2)	J-42(2)	1000	45.8	110738.54	1.63	130	2.05
P-2089	J-1648	J-2037	1000	34.3	64650.03	0.95	130	0.76
P-2851	J-2921	J-3001	1600	34.6	308928.49	1.78	130	1.39
P-1357	J-1262	J-1454	300	34.6	2169.18	0.36	110	0.68
P-506	J-2039	J-1008	300	34.7	3427.32	0.56	130	1.16
P-315	J-1040	J-790	250	35.0	0.00	0.00	110	0.00
P-1405	J-2043	J-189	250	35.0	2049.19	0.48	110	1.48
P-944	J-1936	J-1820	250	35.1	1251.63	0.30	110	0.59
P-2915	J-2044	J-1836	1400	35.2	307712.45	2.31	130	2.65

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2103	J-1331	J-868	1000	35.8	62365.73	0.92	130	0.71
P-85	J-1253	J-2046	300	35.8	0.00	0.00	110	0.00
P-2508	J-1108	J-1847	600	35.9	36630.40	1.50	130	3.19
P-257	J-2038	J-1976	250	36.0	0.00	0.00	130	0.00
P-591	J-2015	J-2016	250	36.3	1921.19	0.45	130	0.96
P-2652	J-2049	J-2050	500	36.3	17251.80	1.02	130	1.92
P-208	J-1209	J-2036	300	36.3	0.00	0.00	130	0.00
P-2634	J-2999	J-3000	500	36.6	26231.99	1.55	130	4.17
P-1913	J-1654	J-2047	250	36.8	3157.72	0.74	110	3.30
P-2202	J-2235	J-2786	500	37.2	20112.51	1.19	130	2.55
P-961	J-1292	J-921	300	37.0	1741.23	0.29	110	0.45
P-972	J-1918	J-416	300	37.1	1692.34	0.28	110	0.43
P-124	J-1969	J-1666	400	37.1	0.00	0.00	130	0.00
P-751	J-1990	J-1991	300	37.3	0.00	0.00	130	0.00
P-1358	J-1274	J-1014	300	37.4	2169.18	0.36	110	0.68
P-1932	J-452	J-774	250	37.6	2789.95	0.66	130	1.93
P-628	J-2053	J-2054	250	37.6	1921.19	0.45	130	0.96
P-1248	J-2171	J-1244	250	37.7	1674.94	0.39	130	0.75
P-1359	J-1430	J-996	300	38.2	2169.18	0.36	110	0.68
P-2444	J-1807	J-1699	400	38.4	13372.97	1.23	130	3.55
P-1315	J-516	J-248	600	38.6	25640.80	1.05	130	1.65
P-1386	J-2060	J-1096	250	41.6	2755.55	0.65	110	2.56
P-2952	J-856	J-1850	250	38.9	12572.80	2.96	110	42.63
P-1008	J-2063	J-2064	300	38.9	1684.03	0.28	130	0.31
P-1779	J-50(2)	J-439	300	39.0	4117.18	0.67	130	1.63
P-2362	J-2065	J-744	400	75.0	12289.08	1.13	110	4.14
P-2176	J-2786	J-1598	500	44.7	12523.53	0.74	130	1.06
P-1406	J-64	J-2043	250	39.2	2049.19	0.48	110	1.48
P-2871	J-1878	J-1514	250	41.9	10013.04	2.36	130	20.52
P-2673	J-1955	J-1349	600	39.5	50227.99	2.06	130	5.72
P-2079	J-2069	J-2070	300	39.8	3947.94	0.65	130	1.51
P-2879_SPL2	J31283	J-2208	300	51.8	0.01	0.00	130	0.00
P-1058	J-2071	J-2072	250	39.9	1323.27	0.31	110	0.66
P-1923	J-3177	J-3178	250	36.0	3118.40	0.74	130	2.37
P-918	J-799	J-2961	800	41.8	5816.01	0.13	130	0.03
P-2587	J-1710	J-2073	400	40.1	12216.60	1.13	130	3.01
P-1360	J-1197	J-1450	300	40.2	2169.18	0.36	110	0.68
P-1177	J-496	J-2074	250	40.3	1472.19	0.35	110	0.80
P-1361	J-1247	J-1293	300	40.3	2169.18	0.36	110	0.68
P-1945	J-1257	J-2116	250	40.4	2789.95	0.66	130	1.93
P-1933	J-2077	J-2078	250	40.5	2789.95	0.66	130	1.93
P-627	J-2058	J-1117	250	40.5	1921.19	0.45	130	0.96
P-962	J-1597	J-1762	300	40.5	1741.23	0.29	110	0.45

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2278	J-2079	J-2080	300	40.7	3478.07	0.57	130	1.19
P-2658_SPL2	J16741	J-1584	1000	42.3	91858.39	1.35	130	1.45
P-1362	J-1276	J-1279	300	41.1	2169.18	0.36	110	0.68
P-973	J-2081	J-2082	300	41.3	1692.34	0.28	110	0.43
P-5	J-2106	J-1705	250	41.3	0.00	0.00	130	0.00
P-2748	J-819	J-1489	1200	49.1	159108.72	1.63	130	1.65
P-633	J-2083	J-2053	250	41.4	1921.19	0.45	130	0.96
P-1178	J-1603	J-2084	250	42.9	1472.19	0.35	110	0.80
P-2405	J-2085	J-540	800	60.4	57443.49	1.32	130	1.81
P-1307	J-758	J-2086	250	41.9	1191.17	0.28	110	0.54
P-37	J-2002	J-2087	600	42.0	27953.57	1.14	130	1.93
P-569	J-38	J-462	300	42.4	0.00	0.00	130	0.00
P-1882	J-2088	J-1550	300	42.6	4948.92	0.81	130	2.29
P-89	J-2046	J-2089	300	42.7	0.00	0.00	110	0.00
P-2523	J-375	J-2090	1200	42.8	108998.13	1.12	130	0.82
P-1497	J-2091	J-2092	300	42.8	2685.45	0.44	130	0.74
P-1414	J-2093	J-2094	600	42.9	22359.20	0.92	130	1.28
P-2243	J-2682	J-2967	450	43.0	14361.52	1.05	110	3.11
P-2625_SPL2	J31289	J-444	600	43.1	50227.99	2.06	130	5.72
P-1859_SPL1	J-2670	J48182	500	43.2	16626.61	0.98	130	1.79
P-1130	J-2095	J-584	300	43.2	1936.00	0.32	130	0.40
P-2265	J-2096	J-2097	300	43.2	3478.07	0.57	130	1.19
P-2929	J-2099	J-1005	1600	43.4	414116.41	2.38	130	2.39
P-2923	J-1984	J-604	1350	47.6	326498.94	2.64	110	4.81
P-501	J-143	J-55	300	45.0	0.00	0.00	130	0.00
P-625	J-2102	J-2103	250	44.1	1921.19	0.45	130	0.96
P-3031	J-3006	J-3007	600	44.2	109803.21	4.49	130	24.35
P-1795	J-1927	J-3205	225	44.3	993.60	0.29	130	0.48
P-2066	J-306	J-289	1000	44.9	56385.85	0.83	130	0.59
P-2191_SPL1	J-2912	J21545	500	55.9	47308.80	2.79	130	12.44
P-1041_SPL4	J21555	J-1631	300	45.1	1344.88	0.22	130	0.20
P-2198_SPL2	J2	J-3106	600	45.2	17260.97	0.71	130	0.79
P-1729	J-619	J-284	500	45.5	14016.09	0.83	130	1.31
P-2094	J-2114	J-1363	300	45.5	7988.47	1.31	130	5.56
P-1697	J-2115	J-1150	250	45.6	2619.78	0.62	110	2.33
P33969_SPL2	J-2824	J5580	600	49.1	14161.61	0.58	130	0.55
P-1179	J-2074	J-1532	250	45.7	1472.19	0.35	110	0.80
P-1967	J11167	J-3048	250	45.9	3160.00	0.75	130	2.42
P-1720	J-27	J-1948	1000	46.1	34418.30	0.51	130	0.24
P-487	J-2121	J-638	250	48.8	0.00	0.00	130	0.00
P22338	J22939	J22859	225	46.2	2729.11	0.79	130	3.09
P-2961	J-2614	J-3204	500	46.4	49968.00	2.95	130	13.77
P-1684	J-1171	J-2122	800	48.2	29551.03	0.68	130	0.53

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1934	J-775	J-520	250	49.4	2789.95	0.66	130	1.93
P-2279	J-2123	J-1726	300	46.7	3478.07	0.57	130	1.19
P-1674	J-1853	J-2124	300	46.7	5055.25	0.83	130	2.38
P-1917	J-2112	J-2113	400	47.0	8710.55	0.80	130	1.61
P-2794	J-684	J-1756	1600	47.3	307712.45	1.77	130	1.38
P-1180	J-2084	J-2006	250	47.3	1472.19	0.35	110	0.80
P-1363	J-1368	J-606	300	47.6	2169.18	0.36	110	0.68
P-1823	J-3169	J-3170	300	47.7	4152.00	0.68	130	1.65
P-1689	J-2219	J-2970	800	47.8	29449.13	0.68	130	0.52
P-290	J-1042	J-2127	250	47.9	0.00	0.00	110	0.00
P-3054	J-79	J-80	400	47.9	81941.36	7.55	130	102.04
P-1321	J-2128	J-2129	250	48.0	1902.63	0.45	110	1.29
P-1297	J-2130	J-1054	250	48.0	1191.17	0.28	110	0.54
P-1075	J-1268	J-514	300	48.1	1751.59	0.29	110	0.46
P-2452	J-776	J-1943	900	48.1	76477.12	1.39	110	2.36
P-1536	J-2152	J-1125	250	48.3	1771.97	0.42	130	0.83
P-1298	J-1055	J-2131	250	48.4	1191.17	0.28	110	0.54
P-90	J-1671	J-1460	300	48.5	0.00	0.00	110	0.00
P-801	J-648	J-421	250	48.5	556.13	0.13	130	0.10
P-2119	J-2899	J-1531	800	53.3	50568.14	1.16	130	1.43
P-1233	J-1938	J-2132	250	48.6	1741.24	0.41	110	1.10
P-1773	J-535	J-1733	400	48.7	6835.19	0.63	130	1.03
P-963	J-1580	J-1619	300	48.9	1741.23	0.29	110	0.45
P-1059	J-2072	J-1610	250	49.0	1323.27	0.31	110	0.66
P-2750	J-3137	J-3138	300	49.2	11436.80	1.87	130	10.80
P-291	J-2136	J-87	250	49.2	0.00	0.00	110	0.00
P-1990	J-2134	J-2135	300	49.4	3099.34	0.51	130	0.96
63036	J41931	J41928	300	49.5	5857.71	0.96	130	3.13
P-1733	J-967	J-2138	300	49.6	3741.52	0.61	110	1.86
P-645	J-2139	J-2140	250	49.8	1031.26	0.24	130	0.30
P-743	J-2141	J-2142	300	49.8	0.01	0.00	130	0.00
P-3047	J-951	J-698	400	51.7	63965.41	5.89	130	64.50
P-2280	J-2143	J-2123	300	50.0	3478.07	0.57	130	1.19
P-1163	J-1579	J-1659	250	50.5	1477.98	0.35	110	0.81
P-3015	J-1494	J-1206	300	50.7	0.00	0.00	130	0.00
P-1740	J-1779	J-1700	500	50.8	10088.01	0.59	130	0.71
P-1299	J-2131	J-2145	250	50.9	1191.17	0.28	110	0.54
P-494	J-2146	J-2147	250	55.4	0.00	0.00	130	0.00
P-2018	J-3173	J-3174	300	51.1	4856.00	0.80	130	2.21
P-802	J-2149	J-2150	250	51.2	556.13	0.13	130	0.10
P-3045	J-772	J-699	400	52.7	63084.90	5.81	130	62.87
P-2266	J-2154	J-2155	300	51.6	3478.07	0.57	130	1.19
P-1322	J-2156	J-2128	250	51.9	1902.63	0.45	110	1.29

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-989	J-2157	J-2158	250	52.0	1276.65	0.30	110	0.62
P-313	J-1302	J-1661	300	52.0	0.00	0.00	110	0.00
P-1300	J-2145	J-2159	250	52.1	1191.17	0.28	110	0.54
P-2406_SPL3	J21556	J21551	800	52.6	40894.53	0.94	130	0.96
P-990	J-2158	J-1806	250	52.7	1276.65	0.30	110	0.62
P-1655	J-2162	J-2163	250	53.1	3620.35	0.85	110	4.25
P-2781	J-583	J-943	1400	53.3	271033.27	2.04	110	2.85
P-1164	J-1309	J-2165	250	53.3	1477.98	0.35	110	0.81
P-1809	J-2166	J-2167	250	53.4	3680.00	0.87	130	3.21
P-1708	J-840	J-1265	300	56.2	1401.17	0.23	130	0.22
P-2030	J-3096	J-3152	600	53.5	0.00	0.00	130	0.00
P-149	J-509	J-738	300	55.2	0.00	0.00	110	0.00
P-861	J-1656	J-2148	300	53.9	0.00	0.00	130	0.00
P-1415	J-1124	J-2093	600	54.4	22359.20	0.92	130	1.28
P-2547	J-2173	J-1535	1000	55.0	101787.81	1.50	110	2.39
P-1675	J-2174	J-2175	300	54.4	5055.25	0.83	130	2.38
P-2610	J-1110	J-2178	400	54.6	16405.88	1.51	110	7.07
P-964	J-1435	J-1291	300	54.6	1741.23	0.29	110	0.45
P-1021	J-1192	J-2179	300	54.7	1684.03	0.28	130	0.31
P-696	J-1534	J-2254	300	55.8	1431.73	0.23	130	0.23
P-1364	J-2181	J-1367	300	55.0	2169.18	0.36	110	0.68
P-1664	J-2182	J-2183	250	55.4	392.21	0.09	130	0.05
P-1828	J-1611	J-1188	300	55.4	4542.48	0.74	110	2.66
P-3004	J-1362	J-2184	400	55.4	37585.90	3.46	130	24.09
P-738	J-2180	J-1657	300	55.4	0.01	0.00	130	0.00
P-1301	J-2185	J-2130	250	55.5	1191.17	0.28	110	0.54
P-132	J-36	J-2186	300	55.5	0.00	0.00	110	0.00
P-974	J-2187	J-192	300	55.6	1692.34	0.28	110	0.43
P-1302	J-2159	J-752	250	55.6	1191.17	0.28	110	0.54
P-687	J-1030	J-2161	300	55.8	0.00	0.00	130	0.00
P-2724	J-98	J-2185	250	55.7	7575.81	1.79	110	16.68
P-2393	J-2188	J-2189	400	55.9	12704.18	1.17	130	3.23
P-1482	J-824	J-2168	500	56.0	16626.61	0.98	130	1.79
P-629	J-2103	J-2190	250	56.1	1921.19	0.45	130	0.96
P57100	J56959	J56960	250	56.1	0.00	0.00	130	0.00
P-1905	J-1776	J-2191	250	56.6	3213.43	0.76	110	3.41
P-1009	J-1544	J-2063	300	56.8	1684.03	0.28	130	0.31
P-2281	J-2080	J-2143	300	56.8	3478.07	0.57	130	1.19
P-2856	J-3007	J-3014	600	56.8	55502.41	2.27	130	6.88
P-6	J-2980	J-2718	500	57.1	0.00	0.00	130	0.00
P-975	J-417	J-2081	300	57.5	1692.34	0.28	110	0.43
P-423	J-2195	J-2196	300	57.5	0.00	0.00	130	0.00
P-1323	J-2197	J-2156	250	57.6	1902.63	0.45	110	1.29

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m³/day)	V (m/s)	C	I (‰)
P-305	J-2198	J-2106	250	57.7	0.00	0.00	130	0.00
P-2068	J-1566	J-3109	400	58.0	5400.60	0.50	130	0.66
P-2208	J-407	J-1234	500	64.4	12012.80	0.71	130	0.98
P-2282	J-2202	J-2203	300	58.0	3478.07	0.57	130	1.19
P-630	J-2190	J-1011	250	58.1	1921.19	0.45	130	0.96
P-465	J-293	J-2209	300	62.3	0.00	0.00	130	0.00
P-1979	J-2210	J-97	250	58.7	3225.65	0.76	110	3.43
P-2217	J-2200	J-2201	300	58.8	5055.25	0.83	130	2.38
P-965	J-1763	J-1609	300	58.9	1741.23	0.29	110	0.45
P-2283	J-2203	J-2079	300	59.1	3478.07	0.57	130	1.19
P-1324	J-2213	J-2214	250	59.2	1902.63	0.45	110	1.29
P-156	J-2204	J-2205	300	69.9	3427.32	0.56	130	1.16
P-2611	J-2178	J-744	400	59.3	16405.88	1.51	110	7.07
P-759	J-3025	J-3026	500	59.5	1262.39	0.07	130	0.02
P-790	J-2215	J-1612	400	59.6	346.67	0.03	110	0.01
P-644	J-2216	J-2217	250	59.7	857.83	0.20	130	0.22
P-1631	J-1275	J-2218	250	60.7	2528.28	0.60	110	2.19
P-2519	J-2924	J-3015	400	59.8	14656.00	1.35	130	4.21
P-2267	J-2221	J-2154	300	60.6	3478.07	0.57	130	1.19
P-1165	J-2165	J-105	250	60.9	1477.98	0.35	110	0.81
P-2015	J-3171	J-3172	300	60.9	4745.60	0.78	130	2.12
P-1734	J-2138	J-880	300	60.9	3741.52	0.61	110	1.86
P-262	J-2205	J-1008	300	61.0	3427.32	0.56	130	1.16
P-1407	J-132	J-2010	250	61.4	2049.19	0.48	110	1.48
P-1365	J-1625	J-2222	300	61.4	2169.18	0.36	110	0.68
P-878	J-2223	J-173	250	68.5	6.25	0.00	130	0.00
P-1120	J-2224	J-2225	500	63.5	5493.11	0.32	110	0.31
P-2268	J-2226	J-1872	300	61.8	3478.07	0.57	130	1.19
P-1366	J-2228	J-1862	300	61.9	2169.18	0.36	110	0.68
P-1846	J-2229	J-1105	250	62.0	2651.62	0.63	130	1.75
P-1991	J-2135	J-1933	300	62.1	3099.34	0.51	130	0.96
P-1790	J-2231	J-2232	250	62.5	1822.28	0.43	110	1.19
P-159	J-176	J-117	300	62.6	0.00	0.00	110	0.00
P-1638	J-3175	J-3176	250	61.4	2257.60	0.53	130	1.30
P-2483	J-393	J-2233	500	62.8	22225.91	1.31	110	4.18
P-111	J-2234	J-1890	300	62.9	0.00	0.00	110	0.00
P-1408	J-880	J-1102	250	63.3	2049.19	0.48	110	1.48
P-95	J-2824	J-3190	400	64.1	0.00	0.00	130	0.00
P-76	J-2230	J-1397	400	63.6	0.00	0.00	130	0.00
P-1499	J-2289	J-1032	300	63.6	2685.45	0.44	130	0.74
P-405	J-2172	J-1703	300	63.9	0.00	0.00	130	0.00
P-1791	J-2232	J-2236	250	64.5	1822.28	0.43	110	1.19
P-536	J-1675	J-2098	250	64.7	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1488	J-2238	J-2239	300	64.9	4366.73	0.72	130	1.82
P-623	J-1751	J-2058	250	65.2	1921.19	0.45	130	0.96
P-1788	J-1375	J-407	600	65.2	10718.41	0.44	130	0.33
P-686	J-2161	J-1883	300	65.3	0.00	0.00	130	0.00
P-1665	J-2242	J-1481	250	65.4	392.21	0.09	110	0.07
P-2080	J-661	J-2069	300	65.8	3947.94	0.65	130	1.51
P-945	J-2243	J-1935	250	66.0	1251.63	0.30	110	0.59
P-3006	J-2914	J-3027	300	77.3	23040.01	3.77	130	39.52
P-1980	J-1013	J-2244	250	66.2	3225.65	0.76	110	3.43
P-94	J-2186	J-2246	300	66.2	0.00	0.00	110	0.00
P-1498	J-2092	J-2286	300	66.3	2685.45	0.44	130	0.74
P-621	J-2054	J-1750	250	66.5	1921.19	0.45	130	0.96
P-158	J-126	J-1421	250	66.3	0.00	0.00	110	0.00
P-573	J-1792	J-2249	250	66.4	978.66	0.23	130	0.28
P-129	J-1173	J-1082	300	66.5	0.00	0.00	110	0.00
P-228	J-2250	J-2035	250	66.5	0.00	0.00	110	0.00
P-1256	J-853	J-840	300	68.6	1401.17	0.23	130	0.22
P-227	J-2251	J-1518	250	66.6	0.00	0.00	110	0.00
P-3056	J-80	J-1475	400	66.7	81941.36	7.55	130	102.04
P-1538	J-2105	J-2279	250	66.8	1771.97	0.42	130	0.83
P-1680	J-2252	J-2253	600	67.0	14361.52	0.59	110	0.77
P-1109	J-2258	J-846	300	67.0	0.00	0.00	130	0.00
P-1325	J-2214	J-1822	250	67.2	1902.63	0.45	110	1.29
P-112	J-1890	J-2255	300	69.5	0.00	0.00	110	0.00
P-2011	J-2256	J-1778	900	68.3	43803.20	0.80	130	0.62
P-35	J-498	J-2259	500	71.9	0.00	0.00	130	0.00
P-1567	J-2270	J-2271	400	69.1	4143.68	0.38	130	0.41
P-831	J-223	J-2260	300	69.4	1200.23	0.20	130	0.17
P-1242	J-1379	J-2261	250	69.5	1692.34	0.40	110	1.04
P-2833	J-3217	J-1985	300	78.3	14311.89	2.34	130	16.36
P-1076	J-1392	J-2262	300	69.5	1751.59	0.29	110	0.46
P-976	J-2082	J-2263	300	70.2	1692.34	0.28	110	0.43
P-217	J-168	J-89	250	71.0	0.00	0.00	110	0.00
P-727	J-2264	J-1887	450	71.1	297.91	0.02	110	0.00
P-419	J-2268	J-2172	300	79.2	0.00	0.00	130	0.00
P-593	J-2272	J-2016	250	71.3	1921.19	0.45	130	0.96
P-2524	J-360	J-2269	1200	71.3	108998.13	1.12	130	0.82
P-160	J-1662	J-1670	300	71.3	0.00	0.00	110	0.00
P-2269	J-1873	J-2221	300	71.4	3478.07	0.57	130	1.19
P-926	J-277	J-2992	500	71.5	4163.19	0.25	130	0.14
P-2141	J-3020	J-3021	500	71.7	15360.00	0.91	130	1.55
P-162	J-1251	J-35	300	71.6	0.00	0.00	110	0.00
P-1077	J-2274	J-2275	300	72.2	1751.59	0.29	110	0.46

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2877	J-974	J-1041	300	77.4	16053.84	2.63	110	27.58
P-1935	J-2078	J-2277	250	72.7	2789.95	0.66	130	1.93
P-1290	J-715	J-2236	250	72.5	4577.83	1.08	110	6.56
P-2848	J-1817	J-1802	700	87.3	75566.25	2.27	110	7.84
P-88	J-1083	J-1994	300	72.7	0.00	0.00	110	0.00
P-221	J-1519	J-2276	250	72.9	0.00	0.00	110	0.00
P-2791	J-217	J-1930	1600	74.1	307712.45	1.77	130	1.38
P-2081	J-2280	J-2070	300	74.3	3947.94	0.65	130	1.51
P-1632	J-2281	J-2218	250	74.4	2528.28	0.60	110	2.19
P-31	J-2282	J-2283	500	77.5	0.00	0.00	130	0.00
P-230	J-1773	J-2284	250	74.9	0.00	0.00	130	0.00
P-1243	J-1067	J-1378	250	74.9	1692.34	0.40	110	1.04
P-1992	J-2285	J-1809	300	77.9	3099.34	0.51	130	0.96
P-2185	J-1743	J-1788	400	75.2	10605.05	0.98	130	2.31
P-2284	J-1727	J-1241	300	75.9	3478.07	0.57	130	1.19
P-2660	J-980	J-101	250	75.9	6700.80	1.58	110	13.29
P-609	J-1968	J-1328	250	77.1	0.00	0.00	130	0.00
P-1409	J-190	J-39	250	77.8	2049.19	0.48	110	1.48
P-1799	J-3193	J-3139	600	77.1	18887.82	0.77	130	0.93
P-386	J-2295	J-908	300	77.4	0.00	0.00	130	0.00
P-1946	J-2296	J-781	250	77.6	2789.95	0.66	130	1.93
P-1656	J-2297	J-1964	250	78.4	3620.35	0.85	110	4.25
P-2235	J-2335	J-1113	500	78.4	13444.68	0.79	130	1.21
P-229	J-2290	J-2250	250	80.1	0.00	0.00	110	0.00
P-739	J-795	J-924	300	79.2	0.01	0.00	130	0.00
P-1993	J-2299	J-2285	300	79.6	3099.34	0.51	130	0.96
P-180	J-448	J-2300	300	86.3	0.00	0.00	130	0.00
P-138	J-2284	J-2301	250	80.8	0.00	0.00	130	0.00
P-450	J-90	J-2304	250	81.2	0.00	0.00	110	0.00
P-1936	J-877	J-2302	250	81.5	2789.95	0.66	130	1.93
P-643	J-2140	J-2309	250	81.8	1031.26	0.24	130	0.30
P-2648	J-2291	J-1827	300	87.6	8538.92	1.40	130	6.29
P-220	J-2018	J-2311	250	82.0	0.00	0.00	110	0.00
P-241	J-2276	J-1426	250	82.2	0.00	0.00	110	0.00
P6	J-3153	J-3209	2000	14.3	411604.14	1.52	130	0.80
P-488	J-86	J-2312	300	82.9	0.00	0.00	110	0.00
P-2005	J-2946	J-3029	500	83.2	12972.80	0.76	130	1.13
P-1166	J-221	J-486	250	85.2	1477.98	0.35	110	0.81
P-224	J-2311	J-1076	250	83.9	0.00	0.00	110	0.00
P-632	J-1012	J-2083	250	86.1	1921.19	0.45	130	0.96
P-2573	J-1634	J-2315	600	84.1	10212.80	0.42	130	0.30
P-1515	J-1163	J-2316	500	84.4	6330.34	0.37	130	0.30
P-1326	J-1823	J-2317	250	84.4	1902.63	0.45	110	1.29

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2552	J-1442	J-459	400	84.5	0.00	0.00	130	0.00
P-1022	J-1697	J-2318	300	84.5	1684.03	0.28	130	0.31
P-2270	J-2320	J-2321	300	84.6	3478.07	0.57	130	1.19
P-1735	J-1238	J-2323	300	85.7	3741.52	0.61	110	1.86
P-2460	J-3097	J-3147	1400	84.9	149557.98	1.12	130	0.70
P-2533	J-2324	J-672	250	85.0	4429.20	1.04	110	6.17
P-1078	J-713	J-2325	300	85.4	1751.59	0.29	130	0.33
P-695	J-2328	J-2254	300	86.0	1431.73	0.23	130	0.23
P-1847	J-1106	J-396	250	86.1	2651.62	0.63	130	1.75
P-595	J-1038	J-2015	250	86.9	1921.19	0.45	130	0.96
P-1887	J-2875	J-2565	300	87.0	4948.92	0.81	130	2.29
P-1698	J-25	J-2115	250	87.2	2619.78	0.62	110	2.33
P-2694	J-1409	J-3206	300	87.2	10233.60	1.68	130	8.79
P-2145	J-2337	J-2338	250	87.4	2977.02	0.70	130	2.17
P-2843	J-3134	J-3135	300	87.4	13783.99	2.26	130	15.26
P-1849	J-2341	J-2229	250	87.9	2651.62	0.63	130	1.75
P-1736	J-2323	J-1856	300	87.9	3741.52	0.61	110	1.86
P-998	J-330	J-1961	250	88.4	1351.02	0.32	110	0.68
P-2088_SPL1	J-320	J51499	300	88.4	3947.94	0.65	130	1.51
P-567	J-734	J-2198	250	88.6	0.00	0.00	130	0.00
P-451	J-2304	J-2332	250	88.8	0.00	0.00	110	0.00
P-1410	J-40	J-1865	250	89.5	2049.19	0.48	110	1.48
P-1657	J-2334	J-2297	250	89.5	3620.35	0.85	110	4.25
P-1811	J-2343	J-2001	250	90.0	3680.00	0.87	130	3.21
P-3021	J-2336	J-1838	300	90.0	24945.48	4.08	130	45.79
P-1658	J-1868	J-1784	250	102.6	3620.35	0.85	130	3.12
P-896	J-2340	J-2060	250	90.4	1377.78	0.32	110	0.71
P-897	J-2340	J-2060	250	90.4	1377.78	0.32	110	0.71
P-1489	J-2239	J-1963	300	90.4	4366.73	0.72	130	1.82
P-251	J-1503	J-2333	250	90.6	1921.19	0.45	130	0.96
P-1411	J-1103	J-63	250	90.6	2049.19	0.48	110	1.48
P-137	J-2342	J-1373	250	90.7	0.00	0.00	130	0.00
P-2175	J-1522	J-1735	450	90.9	13384.92	0.97	110	2.73
P-1659	J-1858	J-2162	250	91.0	3620.35	0.85	110	4.25
P-219	J-833	J-1186	250	91.2	0.00	0.00	110	0.00
P-223	J-1914	J-2251	250	93.3	0.00	0.00	110	0.00
P-1869	J-2345	J-535	250	91.6	2685.45	0.63	130	1.79
P-1848	J-397	J-787	250	92.5	2651.62	0.63	130	1.75
P-1710	J-1703	J-2040	300	93.0	1401.17	0.23	130	0.22
P-1812	J-1352	J-2346	250	93.2	3680.00	0.87	130	3.21
P-1721	J-326	J-2347	1000	93.3	34418.30	0.51	130	0.24
P-141	J-2348	J-2349	250	96.4	0.00	0.00	110	0.00
P-1327	J-2129	J-317	250	98.3	1902.63	0.45	110	1.29

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2498	J-1795	J-1600	1000	94.2	98137.67	1.45	110	2.24
P-803	J-2150	J-1772	250	94.2	556.13	0.13	130	0.10
P-1167	J-487	J-645	250	94.6	1477.98	0.35	110	0.81
P-2855	J-3139	J-3140	300	94.9	13839.99	2.27	130	15.38
P-999	J-1060	J-2351	250	95.7	1351.02	0.32	110	0.68
P-1542	J-1126	J-1617	250	96.5	1771.97	0.42	130	0.83
P-2574	J-2315	J-1524	600	96.1	10212.80	0.42	130	0.30
P-1810	J-2167	J-2341	250	96.1	3680.00	0.87	130	3.21
P-2763	J-2032	J-2355	1400	96.5	251329.83	1.89	130	1.82
P-2834	J-1986	J-1594	300	96.5	14311.89	2.34	130	16.36
P-1552	J-1422	J-2350	250	97.1	1771.98	0.42	130	0.83
P-2271	J-2155	J-2357	300	97.2	3478.07	0.57	130	1.19
P-728	J-2358	J-1633	450	97.8	297.91	0.02	110	0.00
P-2560	J-41(2)	J-3124	1600	97.8	243282.01	1.40	130	0.89
P-428	J-2359	J-2360	300	97.9	0.00	0.00	130	0.00
P-1751	J-2361	J-2362	400	97.9	16876.80	1.55	130	5.47
P-2584	J-1694	J-2056	250	98.5	5942.37	1.40	130	7.81
P-2645	J-2364	J-2365	800	98.8	64580.95	1.49	130	2.24
P-977	J-193	J-1917	300	102.7	1692.34	0.28	110	0.43
P-2625_SPL1	J-1123	J31289	600	99.4	24538.41	1.00	130	1.52
P-1994	J-2366	J-2367	300	99.5	3099.34	0.51	130	0.96
P-978	J-671	J-2187	300	100.0	1692.34	0.28	110	0.43
P-1244	J-2261	J-1160	250	101.1	1692.34	0.40	110	1.04
P-34	J-2259	J-1401	400	101.5	0.00	0.00	130	0.00
P-1712	J-2368	J-297	300	140.2	4210.88	0.69	130	1.70
P-2764	J-2355	J-2209	1400	101.3	251329.83	1.89	130	1.82
P-2546	J-3034	J-3035	300	101.5	8480.00	1.39	130	6.21
P-2082	J-2379	J-2380	300	102.0	3947.94	0.65	130	1.51
P-1699	J-1151	J-2373	250	102.5	2619.78	0.62	110	2.33
P-1490	J-2374	J-2375	300	102.4	4366.73	0.72	130	1.82
P-2898	J-2370	J-2392	400	103.1	28209.87	2.60	130	14.16
P-1883	J-2378	J-2088	300	103.6	4948.92	0.81	130	2.29
P-2646	J-1668	J-2364	800	129.4	64580.95	1.49	130	2.24
P-680	J-383	J-1681	250	104.0	0.00	0.00	130	0.00
P-82	J-2246	J-322	300	104.1	0.00	0.00	110	0.00
P-1328	J-98	J-2213	250	104.4	1902.63	0.45	110	1.29
P-1761	J-3040	J-3041	250	42.1	2606.40	0.61	130	1.70
P-648	J-2383	J-2139	250	105.0	1031.26	0.24	130	0.30
P-2490	J-2384	J-1384	800	105.1	60338.71	1.39	130	1.98
P-1329	J-2317	J-2197	250	105.3	1902.63	0.45	110	1.29
P-2897	J-1469	J-2370	400	105.6	28209.87	2.60	130	14.16
P-2849	J-1801	J-1906	700	144.5	75566.25	2.27	110	7.84
P-1700	J-2373	J-1601	250	105.8	2619.78	0.62	110	2.33

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2272	J-2357	J-2096	300	105.9	3478.07	0.57	130	1.19
P-2787	J-2385	J-410	1400	106.1	251329.83	1.89	130	1.82
P-832	J-2386	J-2387	300	106.9	1200.23	0.20	130	0.17
P-215	J-197	J-2136	250	107.0	0.00	0.00	110	0.00
P-1491	J-963	J-2374	300	107.0	4366.73	0.72	130	1.82
P-1060	J-797	J-2388	250	107.6	1323.27	0.31	110	0.66
P-1079	J-2389	J-108	300	113.0	1751.59	0.29	110	0.46
P-2775	J-473	J-1440	900	107.9	107546.73	1.96	110	4.43
P-1701	J-1741	J-1746	250	108.1	2619.78	0.62	110	2.33
P-1800	J-3032	J-3033	500	108.3	11268.80	0.66	130	0.87
P-1277	J-900	J-2391	300	109.2	3454.93	0.57	130	1.18
P-729	J-2264	J-2358	450	109.5	297.91	0.02	110	0.00
P-2872	J-1581	J-2397	250	110.5	10013.04	2.36	130	20.52
P-547	J-345	J-377	250	110.6	1921.19	0.45	130	0.96
P-1010	J-2399	J-2400	300	110.6	1684.03	0.28	130	0.31
P-1971	J-2401	J-1001	500	124.0	0.00	0.00	130	0.00
P-1168	J-1156	J-153	250	111.3	1477.98	0.35	110	0.81
P-191	J-2402	J-2403	250	112.0	0.00	0.00	110	0.00
74774	J41928	J41919	300	112.1	5857.71	0.96	130	3.13
P-1553	J-1875	J-2408	250	113.7	1771.98	0.42	130	0.83
P-966	J-1814	J-1230	300	112.4	1741.23	0.29	110	0.45
P-2104	J-2405	J-1648	1000	112.8	62365.73	0.92	130	0.71
P-2088_SPL2	J51498	J-2379	300	113.3	3947.94	0.65	130	1.51
P-2829	J-2420	J-1575	1000	114.2	140689.50	2.07	130	3.20
P-2882	J-3001	J-2945	600	114.5	59052.81	2.42	130	7.72
P-1850	J-2409	J-2410	250	115.3	2651.62	0.63	130	1.75
P22946	J23400	J23392	300	115.4	6836.85	1.12	130	4.17
P-1121	J-2225	J-1074	500	116.3	5493.11	0.32	110	0.31
P-833	J-2412	J-2386	300	116.4	1200.23	0.20	130	0.17
P-693	J-2413	J-2328	300	116.5	1431.73	0.23	130	0.23
P-1871	J-2414	J-2415	250	116.9	2685.45	0.63	130	1.79
P-122	J-2418	J-1717	300	117.2	0.00	0.00	110	0.00
P-252	J-2333	J-1981	250	117.9	1921.19	0.45	130	0.96
P-1947	J-452	J-2419	250	118.0	2789.95	0.66	130	1.93
P-1234	J-802	J-1464	250	118.1	1741.24	0.41	110	1.10
P-1666	J-1482	J-2424	250	120.2	392.21	0.09	110	0.07
P-1645	J-716	J-2425	250	119.9	1915.34	0.45	110	1.31
P14551	J16751	J16757	600	120.4	15184.00	0.62	130	0.62
P-2363	J-1788	J-2065	400	123.2	12289.08	1.13	130	3.04
P-1948	J-2419	J-2422	250	122.1	2789.95	0.66	130	1.93
75713	J41860	J41843	300	121.6	5857.71	0.96	130	3.13
P14549	J16467	J16533	600	128.1	34636.88	1.42	130	2.87
P-2962	J-3118	J-3203	500	122.1	49968.00	2.95	130	13.77

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1271	J-1732	J-2431	250	122.6	1815.14	0.43	110	1.18
P-2083	J-2433	J-660	300	122.6	3947.94	0.65	130	1.51
P-1367	J-1829	J-1342	300	123.0	2169.18	0.36	110	0.68
P-1702	J-2028	J-1745	250	131.3	2619.78	0.62	110	2.33
P-2788	J-314	J-2044	1400	123.7	251329.83	1.89	130	1.82
P-136	J-2434	J-2348	250	123.9	0.00	0.00	110	0.00
P-397	J-2435	J-2436	300	124.0	0.00	0.00	130	0.00
P-172	J-2437	J-2438	300	124.3	2838.95	0.46	130	0.82
P-2095	J-2441	J-2114	300	124.8	7988.47	1.31	130	5.56
P-563	J-1243	J-2442	250	124.9	978.66	0.23	110	0.38
P-842	J-2429	J-1843	600	125.1	28991.57	1.19	130	2.07
P-1792	J-2443	J-2444	250	125.5	1822.28	0.43	110	1.19
P-80	J-7	J-364	300	125.7	0.00	0.00	110	0.00
P-624	J-1118	J-1037	250	125.8	1921.19	0.45	130	0.96
P-1080	J-2445	J-1267	300	125.8	1751.59	0.29	110	0.46
P-2218	J-1839	J-2200	300	125.8	5055.25	0.83	130	2.38
P-2873	J-1582	J-1513	250	126.3	10013.04	2.36	130	20.52
P-2084	J-2380	J-2446	300	126.9	3947.94	0.65	130	1.51
P-2575	J-2447	J-2448	600	126.7	19803.20	0.81	110	1.39
P-2446	J-1699	J-2151	400	128.6	13372.97	1.23	130	3.55
P-1169	J-1777	J-1905	250	129.4	1477.98	0.35	110	0.81
P-558	J-894	J-2453	250	129.7	0.00	0.00	130	0.00
P-131	J-2455	J-1932	250	131.7	0.00	0.00	110	0.00
P-1081	J-2389	J-515	300	132.0	1751.59	0.29	110	0.46
P-1368	J-1455	J-317	300	132.2	2169.18	0.36	110	0.68
P-1418	J-3042	J-3043	500	132.5	8089.60	0.48	130	0.47
P-1667	J-1629	J-2457	250	132.6	392.21	0.09	110	0.07
P-2361	J-1760	J-1557	400	141.6	12289.07	1.13	130	3.04
P-1775	J-1244	J-1590	300	163.2	6992.40	1.14	130	4.34
P-1272	J-2431	J-595	250	133.3	1815.14	0.43	110	1.18
P-1507	J-568	J-2456	300	134.0	2685.45	0.44	130	0.74
P-123	J-2459	J-2460	250	139.3	0.00	0.00	110	0.00
P-69	J-1072	J-258	300	135.2	0.00	0.00	110	0.00
P-3024	J-2946	J-3044	400	135.2	46080.00	4.24	130	35.14
P-2251	J-355	J-1462	450	135.5	14708.19	1.07	110	3.25
P-202	J-125	J-2461	250	135.7	0.00	0.00	110	0.00
P-1235	J-1707	J-1736	250	135.7	1741.24	0.41	110	1.10
P-1813	J-1300	J-2166	250	136.0	3680.00	0.87	130	3.21
P-1236	J-1358	J-1960	250	136.0	1741.24	0.41	110	1.10
P-2394_SPL2	J51508	J-2489	400	136.1	12704.18	1.17	130	3.23
P-2273	J-642	J-2320	300	137.1	3478.07	0.57	130	1.19
P-189	J-162	J-2402	250	137.3	0.00	0.00	110	0.00
P-1127	J-2463	J-1387	400	137.8	5055.25	0.47	130	0.59

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2096	J-2462	J-2441	300	138.0	7988.47	1.31	130	5.56
P-2512	J-236	J-621	800	139.4	64650.03	1.49	130	2.25
P-1214_SPL1	J-2959	J54276	600	138.1	0.00	0.00	130	0.00
P-2389	J-1628	J-972	900	139.6	64029.20	1.16	130	1.24
P22948	J23515	J23473	300	139.0	6836.85	1.12	130	4.17
P-1851	J-2410	J-1863	250	139.3	2651.62	0.63	130	1.75
P-1082	J-2275	J-107	300	139.6	1751.59	0.29	110	0.46
P-2616	J-1922	J-1583	500	139.6	26444.44	1.56	130	4.24
P-2617	J-1922	J-1583	500	139.6	26444.44	1.56	130	4.24
P-923	J-2962	J-3175	800	157.4	18401.60	0.42	130	0.22
P-2085	J-2446	J-2280	300	141.4	3947.94	0.65	130	1.51
P-1193	J-2466	J-2467	250	140.7	1551.04	0.37	110	0.88
P-1011	J-2468	J-2399	300	141.1	1684.03	0.28	130	0.31
P-871	J-3200	J-3201	250	142.2	817.61	0.19	130	0.20
P-2246	J-1554	J-2470	450	142.6	14708.19	1.07	110	3.25
P-697	J-2472	J-2473	300	143.4	1431.73	0.23	130	0.23
P-1793	J-2444	J-2231	250	143.3	1822.28	0.43	110	1.19
P-1308	J-2086	J-1078	250	143.5	1191.17	0.28	110	0.54
P-557	J-2474	J-2475	250	143.7	0.00	0.00	130	0.00
P-640	J-2477	J-1143	250	144.4	857.83	0.20	130	0.22
P-1237	J-1586	J-1553	250	144.7	1741.24	0.41	110	1.10
P-150	J-2300	J-1139	300	145.9	0.00	0.00	130	0.00
P-730	J-1144	J-1633	450	146.3	297.91	0.02	110	0.00
P-1995	J-2480	J-1677	300	145.1	3099.34	0.51	130	0.96
P-782	J-2479	J-1623	400	145.7	1127.90	0.10	130	0.04
P-1170	J-1473	J-2028	250	145.8	1477.98	0.35	110	0.81
P-1000	J-2351	J-1749	250	146.0	1351.02	0.32	110	0.68
P-1852	J-371	J-2409	250	146.8	2651.62	0.63	130	1.75
P-2717	J-246	J-2482	1400	146.9	216552.22	1.63	130	1.38
P-218	J-2483	J-2484	250	147.0	857.83	0.20	130	0.22
P-879	J-2485	J-2223	250	147.5	6.25	0.00	130	0.00
P-637	J-389	J-2486	250	147.3	0.00	0.00	130	0.00
P-1713	J-2039	J-2368	300	147.8	4210.88	0.69	130	1.70
P-400	J-2437	J-784	300	147.9	2838.95	0.46	130	0.82
P-2899	J-2392	J-2487	400	147.9	28209.87	2.60	130	14.16
P-2146	J-1396	J-2527	250	148.4	2977.02	0.70	130	2.17
P-2564	J-3131	J-3039	600	168.7	34558.40	1.41	130	2.86
P-2247	J-1462	J-1554	450	149.5	14708.19	1.07	110	3.25
P-1061	J-2388	J-500	250	149.6	1323.27	0.31	110	0.66
P-2237	J-720	J-2488	500	149.7	13444.68	0.79	130	1.21
P-914	J-1685	J-849	250	149.8	244.27	0.06	110	0.03
P-1369	J-2228	J-1041	300	149.8	2169.18	0.36	110	0.68
P-81	J-1718	J-2312	300	150.0	0.00	0.00	110	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2045	J-1861	J-789	250	150.6	3052.89	0.72	130	2.27
P-1937_SPL2	J51503	J-1200	250	151.0	2789.95	0.66	130	1.93
P-639	J-2491	J-2477	250	152.0	857.83	0.20	130	0.22
P-2509	J-1673	J-760	600	152.2	36630.40	1.50	130	3.19
P-3010	J-826	J-2891	400	153.0	38281.28	3.53	130	24.93
P-1759	J-2493	J-1825	250	153.0	2631.24	0.62	110	2.35
P-1023	J-2494	J-1130	300	153.2	1684.03	0.28	130	0.31
P-1062	J-2495	J-2071	250	153.3	1323.27	0.31	110	0.66
P-1633	J-2498	J-2499	250	153.6	2528.28	0.60	110	2.19
P-2468	J11164	J-3050	300	141.9	7680.01	1.26	130	5.17
P-2179	J-2502	J-2503	400	154.3	8538.93	0.79	130	1.55
P-209	J-2312	J-2459	250	185.7	0.00	0.00	110	0.00
P-1012	J-1568	J-2468	300	154.5	1684.03	0.28	130	0.31
P-1906	J-1688	J-1775	250	154.5	3213.43	0.76	110	3.41
P-2997	J-1239	J-825	400	155.1	36637.68	3.37	130	22.98
P-689	J-2293	J-1029	300	155.0	0.00	0.00	130	0.00
P-1752	J-1316	J-1969	400	155.1	6608.00	0.61	130	0.96
P-67	J-1588	J-2504	300	155.4	0.00	0.00	110	0.00
P-1681	J-669	J-2252	600	204.3	14361.52	0.59	110	0.77
P-642	J-2505	J-2216	250	155.8	857.83	0.20	130	0.22
P-2086	J-2433	J-2520	300	155.6	3947.94	0.65	130	1.51
P-192	J-2461	J-2506	250	156.2	0.00	0.00	110	0.00
P-1914	J-2047	J-871	250	156.6	3157.72	0.74	110	3.30
P-2032	J-3198	J-3199	300	157.1	4953.60	0.81	130	2.29
P-589	J-2508	J-1502	250	157.7	1921.19	0.45	130	0.96
P-268	J-2509	J-2418	300	157.9	0.00	0.00	110	0.00
P-68	J-2510	J-2511	300	158.2	0.00	0.00	110	0.00
P-2254	J-905	J-354	450	159.0	14708.19	1.07	110	3.25
P-694	J-2515	J-2413	300	159.0	1431.73	0.23	130	0.23
P-647	J-2309	J-2516	250	160.1	1031.26	0.24	130	0.30
P-2087	J-491	J-2520	300	160.4	3947.94	0.65	130	1.51
P-2827	J-2517	J-1724	500	160.5	0.00	0.00	130	0.00
P-1295	J-2518	J-2420	1100	160.5	70168.09	0.85	110	0.76
P-51	J-2230	J-2112	400	161.2	0.00	0.00	130	0.00
P-1024	J-2521	J-2494	300	161.8	1684.03	0.28	130	0.31
P-1938	J-1201	J-876	250	162.5	2789.95	0.66	130	1.93
P-1884	J-2524	J-2378	300	163.7	4948.92	0.81	130	2.29
P-77	J-118	J-1071	300	163.9	0.00	0.00	110	0.00
P-1370	J-2222	J-2181	300	164.0	2169.18	0.36	110	0.68
P-915	J-1527	J-1393	250	165.8	244.27	0.06	110	0.03
P-612	J-1892	J-2528	300	166.0	0.00	0.00	130	0.00
P-1083	J-2262	J-2274	300	166.2	1751.59	0.29	110	0.46
P-1480	J-1499	J-1901	300	166.4	3219.22	0.53	110	1.41

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m³/day)	V (m/s)	C	I (‰)
P-1416	J-240	J-2519	600	200.0	25640.80	1.05	130	1.65
P-834	J-2531	J-2532	300	167.6	1200.23	0.20	130	0.17
P-2300	J-776	J-2533	900	167.8	65625.92	1.19	110	1.77
P-193	J-2403	J-2534	250	167.9	0.00	0.00	110	0.00
P-1554	J-2408	J-1665	250	168.3	1771.98	0.42	130	0.83
P-60	J-1783	J-2536	300	168.3	0.00	0.00	110	0.00
P-916	J-1975	J-1709	250	168.5	244.27	0.06	110	0.03
P-1907	J-1324	J-861	250	168.9	3213.43	0.76	110	3.41
P-1314	J-248	J-240	600	170.5	25640.80	1.05	130	1.65
P-1025	J-2537	J-1191	300	169.3	1684.03	0.28	130	0.31
P-197	J-2534	J-2434	250	169.6	0.00	0.00	110	0.00
P-2430	J-281	J-2538	600	170.1	5421.03	0.22	130	0.09
P-1885	J-1355	J-2524	300	170.5	4948.92	0.81	130	2.29
P-1513	J-3139	J-3035	600	171.1	14091.89	0.58	130	0.54
P-1560	J-2975	J-2552	400	171.6	6721.02	0.62	130	0.99
P-2466	J-1710	J-2542	400	172.2	10293.40	0.95	130	2.19
P-1171	J-1399	J-992	250	173.0	1477.98	0.35	110	0.81
P-1026	J-2179	J-2521	300	173.5	1684.03	0.28	130	0.31
P-168	J-196	J-102	250	173.6	0.00	0.00	110	0.00
P-1417_SPL2	J14102	J-2519	600	142.8	25640.80	1.05	130	1.65
P-1676	J-2463	J-2175	300	173.9	5055.25	0.83	130	2.38
P-2220	J-2544	J-1839	300	173.9	5055.25	0.83	130	2.38
P-564	J-2545	J-2546	250	174.3	978.66	0.23	110	0.38
P-2874	J-2397	J-1180	250	174.8	10013.04	2.36	130	20.52
P-835	J-2387	J-1263	300	174.9	1200.23	0.20	130	0.17
P-862	J-2539	J-2540	300	176.9	0.00	0.00	130	0.00
P-1660	J-2163	J-1867	250	175.6	3620.35	0.85	110	4.25
P-2431	J-2547	J-2548	600	176.2	5421.03	0.22	130	0.09
P-979	J-2263	J-1647	300	176.3	1692.34	0.28	110	0.43
P-263	J-2360	J-2435	300	178.2	0.00	0.00	130	0.00
P-898	J-2550	J-2340	250	178.4	1377.78	0.32	110	0.71
P-899	J-2550	J-2340	250	178.4	1377.78	0.32	110	0.71
P-745	J-916	J-2553	300	178.6	0.01	0.00	130	0.00
P-1668	J-2551	J-2242	250	180.0	392.21	0.09	110	0.07
P-1950	J-2549	J-398	250	179.4	2789.95	0.66	130	1.93
P-1516	J-2541	J-1443	500	179.6	6330.34	0.37	130	0.30
P-2991	J-558	J-583	1000	223.0	236571.18	3.49	110	11.42
P22949	J23473	J23451	300	180.6	6836.85	1.12	130	4.17
P-2715	J-1061	J-1046	1400	180.6	238778.62	1.80	110	2.26
P-213	J-577	J-2554	250	183.2	0.00	0.00	110	0.00
P-865	J-2000	J-1400	250	219.8	6.25	0.00	130	0.00
P-1194	J-2467	J-161	250	181.2	1551.04	0.37	110	0.88
P-1492	J-1423	J-1946	300	192.5	4366.73	0.72	130	1.82

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2576	J-2030	J-2447	600	182.1	19803.20	0.81	130	1.02
P-1949	J-2116	J-2549	250	182.1	2789.95	0.66	130	1.93
P-1568	J-2556	J-2270	400	182.3	4143.68	0.38	130	0.41
P-2824	J-754	J-1837	1400	183.4	307712.45	2.31	130	2.65
P-616	J-1884	J-2530	300	188.1	0.00	0.00	130	0.00
P-1966	J-1520	J-2464	300	185.8	4755.19	0.78	130	2.13
P-2341	J-3109	J-2618	400	187.5	19105.33	1.76	130	6.88
P-2219	J-2201	J-1853	300	187.2	5055.25	0.83	130	2.38
P-62	J-624	J-2559	300	187.2	0.00	0.00	110	0.00
P-283	J-688	J-2560	300	187.3	0.00	0.00	130	0.00
P-946	J-626	J-2243	250	187.4	1251.63	0.30	110	0.59
P-1853	J-2558	J-1902	250	187.5	2651.62	0.63	130	1.75
P-2212	J-2561	J-1024	500	234.2	18201.39	1.07	110	2.89
P-1027	J-2318	J-2537	300	244.1	1684.03	0.28	130	0.31
P-1036	J-2562	J-307	300	189.3	0.00	0.00	130	0.00
P-1854	J-77	J-2558	250	189.0	2651.62	0.63	130	1.75
P-1001	J-1088	J-329	250	190.1	1351.02	0.32	110	0.68
P-781	J-1558	J-2563	400	190.3	1127.89	0.10	130	0.04
P-1888	J-2564	J-2565	300	190.3	4948.92	0.81	130	2.29
P-1996	J-1934	J-2566	300	190.7	3099.34	0.51	130	0.96
P-917	J-1417	J-1649	250	191.3	244.27	0.06	110	0.03
P-216	J-1365	J-578	250	192.5	0.00	0.00	110	0.00
P-1245	J-85	J-1161	250	191.8	1692.34	0.40	110	1.04
P-1309	J-1079	J-1663	250	193.9	1191.17	0.28	110	0.54
P-2186	J-2027	J-1743	400	191.9	10605.05	0.98	130	2.31
P-1569	J-2556	J-1048	400	192.0	4143.68	0.38	130	0.41
P-1063	J-501	J-2495	250	192.2	1323.27	0.31	110	0.66
P-1013	J-2064	J-2567	300	193.0	1684.03	0.28	130	0.31
P-631	J-2102	J-666	250	193.2	1921.19	0.45	130	0.96
P-2944	J-3132	J-2914	1000	193.9	188883.21	2.78	130	5.52
P-880	J-2485	J-1495	250	198.9	6.25	0.00	130	0.00
P-1051	J-201	J-185	250	194.7	1305.68	0.31	110	0.64
P-932	J-22	J-732	250	195.8	1222.60	0.29	110	0.57
P-2401	J-2569	J-2570	300	196.3	7137.42	1.17	130	4.51
P-836	J-2260	J-2531	300	196.7	1200.23	0.20	130	0.17
P-190	J-2506	J-1224	250	197.3	0.00	0.00	110	0.00
P-1958	J-2571	J-676	300	201.2	4755.20	0.78	130	2.13
P-559	J-2475	J-1675	250	197.6	0.00	0.00	130	0.00
P-79	J-2554	J-2234	300	197.6	0.00	0.00	110	0.00
P-1518	J-427	J-1163	500	198.0	6330.34	0.37	130	0.30
P-1251	J-129	J-2573	250	199.9	0.00	0.00	130	0.00
P-2108	J-492	J-1834	900	198.6	49488.22	0.90	110	1.05
P-1727	J-58	J-2575	1100	198.8	63805.29	0.78	110	0.63

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1981	J-2244	J-1500	250	199.3	3225.65	0.76	110	3.43
P-1413	J-3196	J-3197	250	199.4	2003.20	0.47	130	1.04
P-271	J-188	J-2576	250	199.8	0.00	0.00	130	0.00
P-1547	J-2577	J-2308	250	200.7	1771.97	0.42	130	0.83
P-837	J-199	J-2412	300	201.8	1200.23	0.20	130	0.17
P-1379	J-1146	J-2578	300	202.1	3009.83	0.49	130	0.91
P-2517	J-2338	J-2341	250	202.1	5023.60	1.18	130	5.72
P-1122	J-2580	J-2233	500	216.4	5493.11	0.32	110	0.31
P-120	J-88	J-2584	250	204.0	0.00	0.00	110	0.00
P-783	J-2563	J-2479	400	204.1	1127.90	0.10	130	0.04
P-1677	J-2124	J-2174	300	211.6	5055.25	0.83	130	2.38
P-552	J-1773	J-2582	250	204.3	2003.20	0.47	130	1.04
P-866	J-173	J-1999	250	215.5	6.25	0.00	130	0.00
P-1669	J-2424	J-2182	250	206.8	392.21	0.09	130	0.05
P-1746	J-1255	J-2568	500	205.8	26284.60	1.55	130	4.19
P-1634	J-2588	J-2498	250	206.6	2528.28	0.60	110	2.19
P-698	J-2589	J-390	300	206.7	0.01	0.00	110	0.00
P-45	J-1530	J-1907	400	207.9	0.00	0.00	130	0.00
P-2432	J-2590	J-1927	600	207.9	5421.03	0.22	130	0.09
P-2433	J-2538	J-2547	600	208.6	5421.03	0.22	130	0.09
P-1951	J-782	J-2422	250	208.9	2789.95	0.66	130	1.93
P-2148	J-347	J-2593	250	209.8	2977.02	0.70	130	2.17
P-279	J-2196	J-2594	300	210.0	0.00	0.00	130	0.00
P-2147	J-2593	J-2337	250	210.1	2977.02	0.70	130	2.17
P-1672	J-1859	J-2595	400	210.2	5942.37	0.55	130	0.79
P-1084	J-2596	J-2445	300	210.9	1751.59	0.29	110	0.46
P-1181	J-2598	J-495	250	210.9	1472.19	0.35	110	0.80
P-1548	J-1618	J-2577	250	211.2	1771.97	0.42	130	0.83
P-2553	J-2599	J-1441	400	213.5	0.00	0.00	130	0.00
P-2789	J-314	J-2385	1400	211.4	251329.83	1.89	130	1.82
P-140	J-1065	J-2359	300	211.9	0.00	0.00	130	0.00
P-2565	J-93	J-1294	400	213.3	13161.43	1.21	130	3.45
P-151	J-1929	J-1789	300	213.6	0.00	0.00	130	0.00
P-28	J-497	J-2601	500	214.0	0.00	0.00	130	0.00
P-2149	J-764	J-2600	250	214.0	2977.02	0.70	130	2.17
P-2450	J-275	J-1926	600	214.2	6414.63	0.26	130	0.13
P-2274	J-598	J-2097	300	214.8	3478.07	0.57	130	1.19
P-114	J-2040	J-1424	300	221.5	2838.95	0.46	130	0.82
P-2563	J-1844	J-1651	800	217.6	3228.14	0.07	130	0.01
P-2150	J-2602	J-763	250	218.7	2977.02	0.70	130	2.17
P-652	J-140	J-7	300	219.1	0.01	0.00	110	0.00
P-1952	J-399	J-2296	250	219.3	2789.95	0.66	130	1.93
P-2649	J-1459	J-2291	300	222.1	8538.92	1.40	130	6.29

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-78	J-1877	J-390	300	220.0	0.00	0.00	110	0.00
P-1014	J-2400	J-2567	300	250.3	1684.03	0.28	130	0.31
P-2406_SPL2	J21551	J-2085	800	221.7	57443.49	1.32	130	1.81
P-2001	J-3177	J-3084	1000	68.1	44200.91	0.65	130	0.37
P-1098	J-518	J-582	1400	222.1	68424.72	0.51	110	0.22
P-1182	J-2007	J-2598	250	222.4	1472.19	0.35	110	0.80
P-32	J-2601	J-707	500	222.8	0.00	0.00	130	0.00
P-2248	J-2470	J-1692	450	223.2	14708.19	1.07	110	3.25
P-2395	J-2605	J-2606	400	239.8	12704.18	1.17	130	3.23
P-1997	J-2566	J-2299	300	224.6	3099.34	0.51	130	0.96
P-2336	J-3086	J-2872	1200	225.1	96638.28	0.99	130	0.66
P-771	J-2627	J-2628	250	225.9	0.00	0.00	130	0.00
P-641	J-2217	J-2491	250	226.0	857.83	0.20	130	0.22
P-1794	J-1904	J-2443	250	227.4	1822.28	0.43	110	1.19
P-1635	J-2499	J-2281	250	227.6	2528.28	0.60	110	2.19
P-1939	J-2607	J-519	250	228.8	2789.95	0.66	130	1.93
P-102	J-252	J-2609	300	228.7	1089.39	0.18	130	0.14
P-2434	J-2548	J-2590	600	229.1	5421.03	0.22	130	0.09
P-1044	J-1193	J-2608	300	229.5	1344.88	0.22	130	0.21
P-1636	J-556	J-200	250	230.1	2528.28	0.60	110	2.19
P-549	J-2604	J-2582	250	231.1	3955.18	0.93	130	3.67
P-947	J-733	J-2610	250	231.1	1251.63	0.30	110	0.59
P-594	J-2272	J-344	250	231.2	1921.19	0.45	130	0.96
P-74	J-581	J-175	300	231.2	0.00	0.00	110	0.00
P-2600	J-1672	J-1463	500	231.3	15630.66	0.92	130	1.60
P-1517	J-2316	J-2541	500	235.9	6330.34	0.37	130	0.30
P-991	J-186	J-2611	250	233.6	1276.65	0.30	110	0.62
P-650	J-34	J-1452	300	234.5	0.01	0.00	110	0.00
P-1785	J-1222	J-2834	600	234.9	36355.11	1.49	130	3.14
P-2900	J-2830	J-1468	400	236.1	28209.87	2.60	130	14.16
P-2285	J-1540	J-2202	300	238.1	3478.07	0.57	130	1.19
P-1985	J-1864	J-1848	800	238.4	36630.40	0.84	130	0.79
P-1053	J-932	J-277	500	238.1	8588.55	0.51	130	0.53
P-560	J-2546	J-1791	250	241.1	978.66	0.23	110	0.38
P-2978	J-2614	J-2044	600	249.4	56382.63	2.31	130	7.08
P-700	J-8	J-2589	250	240.0	0.01	0.00	110	0.00
P-635	J-2486	J-1289	250	240.1	0.00	0.00	130	0.00
P-1637	J-84	J-2588	250	241.5	2528.28	0.60	110	2.19
P-70	J-1433	J-2510	300	241.0	0.00	0.00	110	0.00
P-1982	J-1501	J-2210	250	242.5	3225.65	0.76	110	3.43
P-1776	J-1395	J-1589	300	243.0	6992.40	1.14	130	4.34
P-1195	J-24	J-2616	250	243.2	1551.04	0.37	110	0.88
P-948	J-1286	J-1937	250	247.7	1251.63	0.30	110	0.59

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1769	J-697	J-814	300	245.0	4039.43	0.66	110	2.14
P-1908	J-2191	J-1959	250	245.8	3213.43	0.76	110	3.41
P-2406_SPL1	J-525	J21556	800	246.4	40894.53	0.94	130	0.96
P-592	J-2442	J-2545	250	246.5	978.66	0.23	110	0.38
P-2402	J-2569	J-2619	300	246.6	7137.42	1.17	130	4.51
P-1279	J-679	J-1841	300	258.6	3454.93	0.57	130	1.18
P-2159_SPL2	J3	J-3054	600	253.3	14134.47	0.58	130	0.55
P-2651	J-3057	J-3058	600	247.7	38016.00	1.56	130	3.41
P-1940	J-2302	J-2077	250	249.7	2789.95	0.66	130	1.93
P23647	J28750	J28751	250	249.0	0.00	0.00	130	0.00
P-2043_SPL1	J-2113	J21552	400	255.1	7608.16	0.70	130	1.25
P-2925	J-1002	J-1439	1000	251.5	153042.18	2.26	130	3.74
P-2927	J-1007	J-1438	1000	251.7	154670.29	2.28	130	3.81
P-1814	J-2346	J-2343	250	252.1	3680.00	0.87	130	3.21
P-1252	J-2573	J-1706	250	256.0	0.00	0.00	130	0.00
P-2631	J-64958	J-3060	500	286.5	26145.59	1.54	130	4.15
P-442	J-2631	J-2632	250	256.0	0.00	0.00	130	0.00
P-2895	J-2919	J-3132	1600	256.8	468963.24	2.70	130	3.01
P-2396	J-3087	J-2605	400	274.4	12704.18	1.17	130	3.23
P-1047	J-2633	J-896	300	256.8	1132.27	0.19	130	0.15
P-1525	J-1827	J-2544	300	257.0	5055.25	0.83	130	2.38
P-1893	J-1484	J-1364	800	257.7	26407.25	0.61	110	0.58
P-1829	J-1189	J-1607	300	257.8	4542.48	0.74	110	2.66
P-1670	J-1784	J-2183	250	259.8	392.21	0.09	130	0.05
P-2180	J-2502	J-3088	400	258.4	8538.93	0.79	130	1.55
P-2397	J-2606	J-2189	400	275.7	12704.18	1.17	130	3.23
P-1760	J-1251	J-2493	250	260.9	2631.24	0.62	110	2.35
P-1067	J-1127	J-2634	300	261.1	1751.59	0.29	130	0.33
P-2275	J-2321	J-2637	300	260.9	3478.07	0.57	130	1.19
P-565	J-1431	J-2638	300	261.1	0.00	0.00	110	0.00
P-2249	J-1692	J-2639	450	262.3	14708.18	1.07	110	3.25
P-1002	J-1962	J-384	250	264.0	1351.02	0.32	110	0.68
P-838	J-2532	J-1830	300	264.5	1200.23	0.20	130	0.17
P-2250	J-2639	J-1522	450	265.1	14708.18	1.07	110	3.25
P-1646	J-2425	J-23	250	266.3	1915.34	0.45	110	1.31
P-2151	J-2527	J-2602	250	266.4	2977.02	0.70	130	2.17
P-877	J-1075	J-670	500	266.5	3443.92	0.20	110	0.13
P-2916	J-1686	J-1116	500	268.5	45108.94	2.66	130	11.39
P-1555	J-2350	J-1874	250	268.8	1771.98	0.42	130	0.83
P-1048	J-321	J-2876	300	269.5	2934.26	0.48	130	0.87
P-2491	J-2642	J-1797	800	269.9	60338.71	1.39	130	1.98
P-3040	J-1111	J-723	400	280.6	53699.73	4.95	130	46.65
P-1889	J-1689	J-2564	300	270.5	4948.92	0.81	130	2.29

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1830	J-1912	J-1088	300	277.4	4542.48	0.74	110	2.66
P-3037	J-2830	J-1348	400	280.8	53065.22	4.89	130	45.64
P-1387	J-2236	J-2550	250	273.7	2755.55	0.65	110	2.56
P-2241	J-1234	J-1215	350	272.6	6141.88	0.74	130	1.61
P-2229	J-1235	J-1214	350	273.5	5870.92	0.71	130	1.48
P-1068	J-2634	J-1218	300	274.6	1751.59	0.29	130	0.33
P-588	J-312	J-2508	250	274.0	1921.19	0.45	130	0.96
P-1859_SPL4	J48183	J-2671	500	275.5	16626.61	0.98	130	1.79
P-1247	J-2901	J-2655	500	278.4	16876.80	0.99	130	1.84
P-992	J-2646	J-2157	250	279.8	1276.65	0.30	110	0.62
P-1214_SPL2	J54276	J-3067	250	278.9	0.00	0.00	130	0.00
P-1815	J-1330	J-1351	250	279.1	3680.00	0.87	130	3.21
P-1269	J-595	J-43(1)	250	279.2	1815.14	0.43	110	1.18
P-2981	J-748	J-663	600	299.1	86759.25	3.55	130	15.74
P-456	J-1789	J-2647	300	300.7	0.00	0.00	130	0.00
P-1561	J-2552	J-2648	400	281.2	6721.02	0.62	130	0.99
P-212	J-801	J-167	250	282.4	0.00	0.00	110	0.00
P-7	J-2568	J-1866	500	283.0	28833.00	1.70	130	4.97
P-1196	J-2616	J-2466	250	283.1	1551.04	0.37	110	0.88
P-804	J-422	J-2149	250	305.7	556.13	0.13	130	0.10
P-54	J-2563	J-2651	400	284.9	0.00	0.00	130	0.00
P-2718	J-2652	J-244	1400	286.5	216552.22	1.63	130	1.38
P-1753	J-2362	J-1315	400	286.7	16876.80	1.55	130	5.47
P-270	J-2438	J-2653	300	287.3	2838.95	0.46	130	0.82
P-8	J-2249	J-718	250	295.6	978.66	0.23	130	0.28
P-75	J-1402	J-2656	300	412.5	0.00	0.00	130	0.00
P-1417_SPL1	J-2094	J14102	600	290.6	22359.20	0.92	130	1.28
P-440	J-529	J-2657	250	290.5	857.83	0.20	130	0.22
P-1998	J-1810	J-2480	300	291.3	3099.34	0.51	130	0.96
P-1253	J-174	J-2659	250	293.4	0.00	0.00	130	0.00
P-1500	J-2289	J-2658	300	293.8	2685.45	0.44	130	0.74
P22945	J23392	J23343	300	294.2	6836.85	1.12	130	4.17
P-1661	J-158	J-2334	250	295.0	3620.35	0.85	110	4.25
P-2403	J-2570	J-874	300	295.3	7137.42	1.17	130	4.51
P-949	J-2610	J-625	250	295.6	1251.63	0.30	110	0.59
P-210	J-92	J-7	250	296.5	0.00	0.00	110	0.00
P-1744	J-3062	J-3063	300	297.8	2528.00	0.41	130	0.66
P-619	J-1800	J-1818	250	298.4	0.00	0.00	130	0.00
P-2674	J-444	J-2698	600	298.7	50227.99	2.06	130	5.72
P33968_SPL2	J-3208	J36701	600	299.9	37796.81	1.55	130	3.38
P-2719	J-539	J-2661	1400	300.9	216552.22	1.63	130	1.38
P-2033	J-1479	J-2663	500	303.4	12519.93	0.74	130	1.06
P54279	J-2859	J-2653	300	304.7	2838.95	0.46	130	0.82

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1420	J-2662	J-2429	600	304.2	30867.17	1.26	130	2.32
P-1131	J-2647	J-2095	300	323.7	1936.00	0.32	130	0.40
P-2774	J-979	J-1628	900	334.7	105211.51	1.91	130	3.12
P-1280	J-2391	J-678	300	309.3	3454.93	0.57	130	1.18
P-2287	J-2872	J-3032	1200	309.7	92940.12	0.95	130	0.61
P-49	J-1538	J-1485	400	310.6	0.00	0.00	130	0.00
P-1501	J-2658	J-2091	300	310.9	2685.45	0.44	130	0.74
P-2525	J-2269	J-468	1200	310.9	108998.13	1.12	130	0.82
P-2530	J-1979	J-2666	400	328.3	14742.39	1.36	130	4.26
P-2244	J-2253	J-2667	450	313.8	14361.52	1.05	110	3.11
P-2353	J-3068	J-2916	800	326.7	50778.92	1.17	130	1.44
P-1254	J-2659	J-130	250	325.5	0.00	0.00	130	0.00
P-2901	J-681	J-2487	400	320.0	28209.87	2.60	130	14.16
P-1493	J-2637	J-2238	300	320.6	4366.73	0.72	130	1.82
P-554	J-2668	J-2474	250	318.2	0.00	0.00	130	0.00
P-2308	J-544	J-1049	500	318.2	18083.20	1.07	130	2.10
P-64	J-909	J-2669	300	320.8	0.00	0.00	130	0.00
P-1961	J-742	J-232	300	318.9	4755.20	0.78	130	2.13
P-603	J-735	J-1799	250	319.3	0.00	0.00	130	0.00
P-1754	J-2655	J-2361	400	321.6	16876.80	1.55	130	5.47
P-1921	J-1062	J-1043	800	323.1	31053.83	0.72	110	0.79
P-1123	J-2580	J-2224	500	346.1	5493.11	0.32	110	0.31
82484	J41919	J41860	300	334.0	5857.71	0.96	130	3.13
P-1172	J-44(1)	J-686	250	324.8	1343.20	0.32	110	0.68
P-2152	J-2600	J-346	250	324.8	2977.02	0.70	130	2.17
P-1999	J-2367	J-2134	300	325.0	3099.34	0.51	130	0.96
P-1380	J-2578	J-457	300	325.1	3009.83	0.49	130	0.91
P22943	J23451	J23446	300	325.4	6836.85	1.12	130	4.17
P-2526	J-468	J-1753	1200	326.6	108998.13	1.12	130	0.82
P-2049	J-2672	J-2673	1000	330.0	34865.76	0.51	130	0.24
P-2236	J-537	J-2335	500	331.9	13444.68	0.79	130	1.21
P-2342	J-2674	J-1821	500	334.6	20925.52	1.23	130	2.75
P-1855	J-2675	J-1168	250	337.3	2651.62	0.63	130	1.75
P-839	J-1264	J-701	300	336.2	1200.23	0.20	130	0.17
P-1481	J-1610	J-1498	300	336.6	3219.22	0.53	110	1.41
P-566	J-2638	J-37	300	336.7	0.00	0.00	110	0.00
P-258	J-376	J-1447	250	337.2	0.00	0.00	130	0.00
P-2492	J-818	J-146	800	338.9	60338.71	1.39	130	1.98
P-555	J-2453	J-2668	250	340.7	0.00	0.00	130	0.00
P-2120	J-1840	J-2899	800	352.0	50568.14	1.16	130	1.43
P-2790	J-971	J-410	1400	346.6	251329.83	1.89	130	1.82
P-2390	J-521	J-972	900	346.6	64029.20	1.16	130	1.24
P-1860	J-2671	J-1764	500	347.3	16626.61	0.98	130	1.79

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2301	J-2533	J-710	900	348.9	65625.92	1.19	130	1.30
P-1972	J-2676	J-2401	500	353.0	0.00	0.00	130	0.00
P-1856	J-1903	J-2675	250	351.8	2651.62	0.63	130	1.75
P-1872	J-2415	J-2677	250	353.0	2685.45	0.63	130	1.79
P-597	J-224	J-474	250	431.5	0.00	0.00	130	0.00
P-1671	J-2457	J-2551	250	356.6	392.21	0.09	110	0.07
P-2156	J-3069	J-3070	500	357.2	15585.60	0.92	130	1.59
P-1873	J-2677	J-928	250	357.0	2685.45	0.63	130	1.79
P-2160	J-420	J-1672	500	357.1	15630.66	0.92	130	1.60
P-840	J-1472	J-198	300	357.2	1200.23	0.20	130	0.17
P-1690	J-2680	J-2219	800	357.7	29449.13	0.68	130	0.52
P-1037	J-308	J-1706	300	364.2	0.00	0.00	130	0.00
P-662	J-1682	J-2678	250	361.3	0.00	0.00	130	0.00
P-2577	J-2448	J-1634	600	362.2	19803.20	0.81	130	1.02
P-1685	J-1171	J-2220	800	366.3	29551.03	0.68	130	0.53
P-1049	J-321	J-2633	300	364.9	1132.27	0.19	130	0.15
P-2111_SPL3	J21568	J1	600	365.4	18513.76	0.76	130	0.90
P-1878	J-872	J-2336	300	367.0	4948.92	0.81	130	2.29
P-44	J-2651	J-617	400	366.7	0.00	0.00	130	0.00
P-61	J-2681	J-2509	300	367.9	0.00	0.00	110	0.00
P-9	J-2699	J-2875	300	370.0	0.00	0.00	130	0.00
P-1093	J-980	J-1275	250	369.7	1214.33	0.29	110	0.56
P-1879	J-260	J-872	300	371.1	4948.92	0.81	130	2.29
P-2245	J-2667	J-2682	450	372.6	14361.52	1.05	110	3.11
P-1041_SPL1	J-2696	J21554	300	374.7	1344.88	0.22	130	0.21
P-1570	J-2271	J-2684	400	375.6	4143.68	0.38	130	0.41
P-1973	J-2687	J-11	500	376.7	0.00	0.00	130	0.00
P-443	J-915	J-377	250	377.9	1921.19	0.45	130	0.96
P-1205	J-1138	J-3069	800	377.9	25834.99	0.59	110	0.56
P-2493	J-1177	J-817	800	378.7	60338.71	1.39	130	1.98
P-2109	J-3002	J-3071	600	379.8	22198.24	0.91	130	1.26
P-1922	J-2282	J-2420	1600	400.0	125036.54	0.72	130	0.26
P-2347	J-932	J-262	500	382.5	22340.56	1.32	130	3.10
P-2738	J-943	J-1061	1400	384.5	248807.36	1.87	110	2.43
P-1783	J-1104	J-690	800	384.6	27223.52	0.63	110	0.62
P-2693	J-2048	J-1953	300	385.3	8538.93	1.40	130	6.29
P-1502	J-2688	J-1785	300	386.2	2685.45	0.44	130	0.74
P-692	J-2473	J-2515	300	387.2	1431.73	0.23	130	0.23
P-1126	J-1387	J-1107	400	387.9	5055.25	0.47	130	0.59
P-649	J-1101	J-2383	250	405.4	1031.26	0.24	130	0.30
P-2276	J-1241	J-2226	300	398.1	3478.07	0.57	130	1.19
P-294	J-1210	J-2691	400	399.0	0.00	0.00	130	0.00
P-36	J-904	J-2692	450	400.0	0.00	0.00	110	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-277	J-2594	J-2693	300	401.5	0.00	0.00	130	0.00
P-2366	J-3102	J-2994	600	403.3	17260.97	0.71	130	0.79
P-452	J-2657	J-2483	250	410.8	857.83	0.20	130	0.22
P-610	J-1453	J-1528	300	409.1	0.00	0.00	110	0.00
P-2309	J-1085	J-543	500	411.3	18083.20	1.07	130	2.10
P-660	J-2678	J-1334	250	411.6	0.00	0.00	130	0.00
P-2077	J-2787	J-447	400	410.8	0.00	0.00	130	0.00
P-1722	J-2695	J-1949	1000	415.5	34418.30	0.51	130	0.24
P-1723	J-1951	J-2695	1000	415.9	34418.30	0.51	130	0.24
P-1238	J-1973	J-2132	250	416.0	1741.24	0.41	110	1.10
P-1511	J-1652	J-1637	300	422.2	2685.45	0.44	130	0.74
P-247	J-2147	J-299	250	423.8	0.00	0.00	130	0.00
P-265	J-2693	J-2631	300	427.4	0.00	0.00	130	0.00
P-105	J-1758	J-783	300	429.4	2838.95	0.46	130	0.82
P33967	J-3209	J36697	600	431.0	37796.81	1.55	130	3.38
P-1262	J-1044	J-368	250	431.7	1675.42	0.40	130	0.75
P-611	J-2528	J-342	300	445.6	0.00	0.00	130	0.00
P-2261	J-664	J-1364	800	433.9	40475.20	0.93	110	1.29
P-1263	J-369	J-1356	250	436.2	1675.42	0.40	130	0.75
P14552	J16737	J16762	600	628.2	15184.00	0.62	130	0.62
P-1185	J-2871	J-2866	500	445.6	5739.20	0.34	130	0.25
P33968_SPL1	J36697	J-3208	600	442.8	37796.81	1.55	130	3.38
P14548	J16571	J16467	600	443.2	31253.67	1.28	130	2.38
P-109	J-343	J-2195	300	445.0	0.00	0.00	130	0.00
P-2739	J-829	J-1599	400	458.4	18167.50	1.67	130	6.27
P-1042	J-1194	J-2696	300	445.8	1344.88	0.22	130	0.21
P-1562	J-2648	J-483	400	446.7	6721.02	0.62	130	0.99
P-2930	J-1350	J-2099	1600	467.7	414116.41	2.38	130	2.39
P-1834	J-2962	J-3177	1000	351.2	41082.50	0.61	130	0.33
P-1038	J-888	J-2562	300	454.5	0.00	0.00	130	0.00
P-2339	J-1895	J-1546	600	453.7	28844.78	1.18	130	2.05
P-2459	J-1834	J-1449	900	454.0	70102.63	1.28	110	2.01
P-2256	J-2967	J-1122	450	454.5	14708.19	1.07	110	3.25
P-2583	J-3042	J-2949	1200	457.0	130959.87	1.34	130	1.15
P-2720	J-803	J-2652	1400	459.5	216552.22	1.63	130	1.38
P-1954	J-526	J-2701	500	460.3	7138.39	0.42	130	0.37
P22942	J-2868	J23561	300	557.9	6836.85	1.12	130	4.17
P-2675	J-2698	J-1955	600	461.8	50227.99	2.06	130	5.72
P-1045	J-897	J-2608	300	464.1	1344.88	0.22	130	0.21
P-2213	J-2702	J-2703	500	510.8	18201.39	1.07	110	2.89
P-2721	J-2482	J-47	1400	465.4	216552.22	1.63	130	1.38
P-993	J-2611	J-2646	250	473.1	1276.65	0.30	110	0.62
P-2097	J-2031	J-2462	300	475.6	7988.47	1.31	130	5.56

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2505	J-3036	J-3082	400	476.8	14497.60	1.34	130	4.13
P-1816	J-2996	J-1878	500	521.8	11448.01	0.67	130	0.90
P-2722	J-244	J-246	1400	479.5	216552.22	1.63	130	1.38
P-1724	J-2347	J-2704	1000	480.8	34418.30	0.51	130	0.24
P-1039	J-615	J-827	300	487.1	0.00	0.00	130	0.00
P-2668	J-472	J-1190	900	484.8	89589.60	1.63	110	3.16
P-2731	J-3057	J-3083	1000	490.2	118251.20	1.74	130	2.32
P-2000	J-1632	J-2366	300	497.4	3099.34	0.51	130	0.96
P-2494	J-2384	J-2642	800	497.8	60338.71	1.39	130	1.98
P-747	J-2142	J-2451	300	499.3	0.01	0.00	130	0.00
P-1494	J-2375	J-1945	300	514.8	4366.73	0.72	130	1.82
P-121	J-238	J-2705	250	501.2	0.00	0.00	130	0.00
P-2173	J-3032	J-3085	1200	502.8	81671.32	0.84	130	0.48
P-1771	J-391	J-800	300	504.7	4039.43	0.66	110	2.14
P-2451	J-275	J-2614	600	508.9	6414.63	0.26	130	0.13
P-2554	J-144	J-2599	400	515.3	0.00	0.00	130	0.00
P-2534	J-2324	J-1096	250	523.2	4429.20	1.04	110	6.17
P-1383	J-859	J-2707	500	516.1	7816.01	0.46	130	0.44
P-1571_SPL1	J-2684	J21553	400	517.3	4143.68	0.38	130	0.41
P-1421	J-630	J-2662	600	518.9	30867.17	1.26	130	2.32
P-2037	J-1545	J-1062	800	519.7	34609.70	0.80	110	0.96
P-10	J-1843	J-2087	600	524.0	27953.57	1.14	130	1.93
P-2035	J-1787	J-2706	500	525.0	12579.26	0.74	130	1.07
P22950	J23561	J23515	300	526.3	6836.85	1.12	130	4.17
P-1267	J-3119	J-3035	600	530.7	14031.46	0.57	130	0.54
P22947	J23446	J23400	300	530.9	6836.85	1.12	130	4.17
P-2531	J-2666	J-1466	400	613.5	14742.39	1.36	130	4.26
P-2765	J-2209	J-2708	1400	558.8	251329.83	1.89	130	1.82
P-1725	J-2704	J-1950	1000	534.9	34418.30	0.51	130	0.24
P-2527	J-1336	J-2090	1200	537.1	108998.13	1.12	130	0.82
P-2036	J-808	J-2706	500	537.1	12579.26	0.74	130	1.07
P-264	J-2576	J-2146	250	540.6	0.00	0.00	130	0.00
P-2702	J-1796	J-357	800	540.7	72020.95	1.66	130	2.75
P-3005	J-2184	J-829	400	541.3	37585.90	3.46	130	24.09
P-2689	J-1980	J-1536	800	541.6	70405.58	1.62	130	2.63
P-2290	J-484	J-1807	400	544.9	11345.81	1.04	130	2.62
P-2012	J-482	J-2256	900	548.0	43803.20	0.80	130	0.62
P-2376	J-3068	J-3087	600	558.3	27446.56	1.12	130	1.87
P-2630	J-1524	J-2517	600	553.2	0.00	0.00	130	0.00
P-2107	J-2916	J-2924	800	558.1	40687.92	0.94	130	0.95
P-1503	J-2286	J-2688	300	563.1	2685.45	0.44	130	0.74
P-548	J-475	J-238	250	599.4	0.00	0.00	130	0.00
P-2051	J-2673	J-1826	1000	570.7	34865.76	0.51	130	0.24

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1085	J-2325	J-2596	300	574.7	1751.59	0.29	110	0.46
P-2181	J-2503	J-1952	400	579.0	8538.93	0.79	130	1.55
P-1249	J-2171	J-60	250	579.1	1674.94	0.39	130	0.75
P-2214	J-2703	J-857	500	610.4	18201.39	1.07	110	2.89
P-2404	J-2619	J-1145	300	613.3	7137.42	1.17	130	4.51
P-2548	J-2173	J-1795	1000	596.9	101787.81	1.50	110	2.39
P-2090	J-631	J-1893	600	598.4	27251.97	1.12	130	1.84
P-2414	J-2712	J-1859	400	602.8	9955.75	0.92	130	2.06
P-1862_SPL2	J48184	J-2848	500	604.1	16626.61	0.98	130	1.79
P-1384	J-1739	J-1804	500	609.8	7816.01	0.46	130	0.44
P-2034	J-2663	J-1787	500	613.4	12519.93	0.74	130	1.06
P-2007	J-2618	J-1272	400	611.8	6330.35	0.58	130	0.89
P-1691	J-2680	J-1221	800	616.7	29449.13	0.68	130	0.52
P-2131	J-552	J-481	900	617.5	49120.65	0.89	130	0.76
P-2588	J-2713	J-1886	400	617.7	12216.60	1.13	130	3.01
P-758	J-277	J-619	500	621.9	4425.36	0.26	130	0.15
P-2198_SPL1	J-2994	J2	600	814.0	17260.97	0.71	130	0.79
P-1673	J-2595	J-2056	400	651.8	5942.37	0.55	130	0.79
P-1514	J-1443	J-1271	500	630.7	6330.34	0.37	130	0.30
P-1520	J-923	J-1325	500	645.5	6330.34	0.37	130	0.30
P-1209	J-1722	J-2980	500	673.5	6198.40	0.37	130	0.29
P14546	J16762	J16751	600	657.6	15184.00	0.62	130	0.62
P-2875	J-1348	J-1314	250	672.1	10013.04	2.36	130	20.52
P-1924	J-2716	J-641	300	656.3	4473.93	0.73	130	1.90
P-1203	J-2717	J-999	500	657.4	6978.20	0.41	130	0.36
P-2238	J-2488	J-537	500	667.6	13444.68	0.79	130	1.21
P-550	J-1403	J-2604	250	665.9	3955.18	0.93	130	3.67
P-446	J-2792	J-1204	250	684.9	0.00	0.00	130	0.00
P-2416	J-2804	J-2818	800	441.4	58638.67	1.35	130	1.88
P-72	J-2656	J-2295	300	670.8	0.00	0.00	130	0.00
P-2766_SPL2	J22320	J-803	1400	692.6	251329.83	1.89	130	1.82
P-2886	J-2914	J-2987	1000	676.8	165843.20	2.44	130	4.34
P-2227	J-3131	J-3193	800	679.0	43131.20	0.99	130	1.06
P-2467	J-2542	J-1694	400	681.7	10293.40	0.95	130	2.19
P-2398	J-2489	J-2188	400	687.1	12704.18	1.17	130	3.23
P-2658_SPL1	J-1487	J16741	1000	879.1	107042.40	1.58	130	1.93
P-1648_SPL2	J-3089	J-3090	600	691.6	18493.99	0.76	130	0.90
P-2723	J-2661	J-163	1400	706.6	216552.22	1.63	130	1.38
P-757	J-2119	J-2694	300	715.5	0.00	0.00	130	0.00
P-11	J-3069	J-717	800	792.1	10249.39	0.24	110	0.10
P-1313	J-1406	J-870	500	720.7	9429.90	0.56	130	0.63
P-2048	J-2796	J-2797	250	804.1	3052.89	0.72	130	2.27
P-1863	J-2168	J-2670	500	725.3	16626.61	0.98	130	1.79

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2340	J-1893	J-1895	600	729.6	28844.78	1.18	130	2.05
P-1974	J-1771	J-2719	500	747.8	0.00	0.00	130	0.00
P-2759	J-100	J-2258	300	777.4	0.00	0.00	130	0.00
P-1373	J-1815	J-2717	500	740.2	8361.40	0.49	130	0.50
P-273	J-2870	J-3183	300	879.6	0.00	0.00	130	0.00
P-1975	J-12	J-2676	500	754.2	0.00	0.00	130	0.00
P-2134	J-3091	J-2959	600	753.4	0.00	0.00	130	0.00
P-1065	J-2798	J16749	1200	759.8	31253.67	0.32	130	0.08
P-1976	J-2720	J-2687	500	778.7	0.00	0.00	130	0.00
P-2354	J-1437	J-2235	500	780.4	22419.54	1.32	130	3.12
P-2302	J-1598	J-1546	500	779.3	15313.48	0.90	130	1.54
P-1385	J-2707	J-1738	500	784.4	7816.01	0.46	130	0.44
P-2121	J-3054	J-3102	600	794.6	17593.76	0.72	130	0.82
P-434	J-633	J-2033	300	793.9	0.00	0.00	130	0.00
P-1641	J-2575	J-2518	1100	797.5	64944.09	0.79	110	0.65
P33969_SPL1	J36701	J-2824	600	811.9	22838.41	0.93	130	1.33
P-2380	J-3144	J-3002	600	833.7	32678.74	1.34	130	2.58
P-284	J-2691	J-632	400	825.2	0.00	0.00	130	0.00
P-2499	J-766	J-1600	1000	826.3	98428.14	1.45	110	2.25
P-2200	J-3085	J-3036	600	834.7	18814.79	0.77	130	0.93
P-2513	J-622	J-2037	800	855.0	64650.03	1.49	130	2.25
P-1201	J-1480	J-998	500	860.0	6978.20	0.41	130	0.36
P-2685	J-970	J-1045	1000	873.6	118591.17	1.75	110	3.18
P-274	J-3182	J-2844	300	885.1	0.00	0.00	130	0.00
P-2230	J-552	J-521	900	880.4	54977.78	1.00	130	0.94
P-1764	J-1708	J-1940	800	949.5	45424.88	1.05	130	1.17
P-2589	J-2073	J-2713	400	898.5	12216.60	1.13	130	3.01
P-1955	J-2701	J-824	500	909.2	7138.39	0.42	130	0.37
P-2159_SPL1	J-1478	J3	600	915.8	14134.47	0.58	130	0.55
P-2142_SPL1	J-2857	J5586	600	925.5	15690.57	0.64	130	0.66
P-2055	J-3137	J-3193	1000	931.3	51419.73	0.76	130	0.50
P-2550	J-459	J-1210	400	939.2	0.00	0.00	130	0.00
P-1925	J-145	J-2716	300	950.8	4473.93	0.73	130	1.90
P-1133	J-592	J-851	300	952.1	1936.00	0.32	130	0.40
P-2638	J-2843	J-3182	300	967.9	9590.73	1.57	130	7.80
P-2659	J-1911	J-1487	1000	996.1	107042.40	1.58	130	1.93
P-1767	J-3152	J-1965	600	985.2	0.00	0.00	130	0.00
P-222	J-2699	J-2034	300	1008.6	0.00	0.00	130	0.00
P-2435	J-281	J-1409	600	1006.2	5421.03	0.22	130	0.09
P-2749	J-819	J-206	1200	1051.0	159108.72	1.63	130	1.65
P-2518	J-2999	J-3042	1200	1013.6	122870.27	1.26	130	1.02
P-2566	J-93	J-1860	400	1031.6	13161.44	1.21	130	3.45
P-2802	J-2804	J-2805	600	1354.7	47612.26	1.95	130	5.18

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2370_SPL2	J-3112	J21563	500	1032.3	18705.33	1.10	130	2.23
P-58_SPL1	J-2806	J21562	300	1034.4	0.00	0.00	130	0.00
P-1858	J-3144	J-2858	1200	1047.5	81825.88	0.84	130	0.48
P-2106	J-1467	J-2996	500	1074.6	14742.39	0.87	130	1.44
P-2060	J-2809	J-3062	400	1083.8	500.36	0.05	130	0.01
P-2647	J-2365	J-1840	800	1163.9	64580.95	1.49	130	2.24
P-462	J-1759	J-1780	300	1126.6	0.00	0.00	130	0.00
P33966	J-69	J36693	600	1130.5	29964.00	1.23	130	2.20
P-889	J-3175	J-44(2)	800	1097.7	16144.00	0.37	130	0.17
P-1875	J-929	J-2345	250	1147.9	2685.45	0.63	130	1.79
P-2142_SPL2	J5586	J-2858	600	1145.6	37624.97	1.54	130	3.35
P-2111_SPL1	J-2978	J21568	600	1146.8	22198.24	0.91	130	1.26
P-1780	J-3110	J-3111	400	1376.5	6889.61	0.63	130	1.04
P-2365	J-2718	J-2795	500	1180.5	18683.21	1.10	130	2.23
P14547	J16757	J16749	600	1179.7	0.00	0.00	130	0.00
P-1686	J-2122	J-798	800	1348.0	29551.03	0.68	130	0.53
P-1173	J-1774	J-2819	250	1281.9	2003.20	0.47	130	1.04
P14550	J16749	J16571	600	1332.4	31253.67	1.28	130	2.38
P-2110	J-3071	J-2978	600	1399.1	22198.24	0.91	130	1.26
P-2337	J-2999	J-3086	1200	1337.6	96638.28	0.99	130	0.66
P-2538	J-2830	J-2831	800	1361.1	61303.28	1.41	130	2.04
P-2777	J-1575	J-979	1000	1421.3	122465.50	1.80	130	2.48
P-2779	J-3065	J-3153	2000	1387.9	411604.14	1.52	130	0.80
P-2372	J-2939	J-3068	1000	1497.7	78225.48	1.15	130	1.08
P-2016	J-1409	J-2833	600	1473.3	6475.43	0.27	130	0.13
P-2205	J-2909	J-3102	600	1485.8	3673.20	0.15	130	0.05
P-59	J-3103	J-3104	300	1820.9	0.00	0.00	130	0.00
P-1565	J-3131	J-3105	500	1738.2	8572.80	0.51	130	0.53
P-2385_SPL2	J22318	J-3112	600	1797.8	21599.51	0.88	130	1.20
P-2876	J-1439	J-1350	1600	1852.4	363888.45	2.09	130	1.88
P-2447	J-3108	J-3109	500	2049.3	24505.93	1.44	130	3.68
P-2002	J-2858	J-3084	1000	1968.2	44200.91	0.65	130	0.37
P-1977	J-2720	J-2719	500	2129.1	0.00	0.00	130	0.00
P-2222	J-3085	J-3137	1000	3777.1	62856.53	0.93	130	0.72
P-2313	J-3147	J-3151	1400	2385.4	122774.46	0.92	130	0.48
P-2885	J-2987	J-3007	1000	2690.9	165305.61	2.44	130	4.31
P-779	J-3115	J-3116	300	3087.8	208.88	0.03	130	0.01
P-2299	J-2950	J-2939	1400	2885.9	130959.87	0.98	130	0.54
P-887	J-3116	J-3103	300	3042.4	1667.92	0.27	130	0.31
P-2697	J-3108	J-3181	1400	3094.5	218776.07	1.64	130	1.41
P-1706	J-3120	J-3121	400	3340.9	5890.46	0.54	130	0.78
P-2008	J-3122	J-3120	400	3442.1	7944.86	0.73	130	1.35
P-2772	J-3001	J-3180	1600	3499.4	249875.67	1.44	130	0.94

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-1208	J-3126	J-3115	300	4653.3	1816.87	0.30	130	0.36
P-2559	J-3124	J-3108	1600	5660.5	243282.01	1.40	130	0.89
P-1522	J-3127	J-3122	500	4611.4	12917.28	0.76	130	1.12
P-1523	J-3090	J-3127	500	4893.0	12917.28	0.76	130	1.12
P-1425	J-3128	J-3129	400	4532.7	5576.71	0.51	130	0.70
P-1559	J-3103	J-3130	300	4615.6	3442.32	0.56	130	1.17
P-1257	J-3121	J-3126	400	7788.7	3986.47	0.37	130	0.38
P-2193_SPL2	J54275	J-3219	600	5404.3	23100.00	0.95	130	1.36
P-1426	J-3129	J-3090	400	5464.7	5576.71	0.51	130	0.70
P-1749	J-3130	J-3128	300	5742.9	4085.52	0.67	130	1.61
P-2542	J-3219	J-3011	500	6785.5	23100.00	1.36	130	3.30
P57101	J57001	J57002	250	1.8	0.00	0.00	130	0.00
P57105	J-3154	J57103	600	16.4	38484.80	1.58	130	3.49
P39445	J-3209	J-3154	2000	2009.8	341641.75	1.26	130	0.57
P57112	J57106	J57107	1800	2498.2	290508.91	1.32	130	0.70
P57120	J-447	J57116	400	107.9	0.00	0.00	130	0.00
P57121	J57116	J57115	400	420.7	0.00	0.00	130	0.00
P-2580_SPL6(1)	J-64921	J57102	2000	483.5	411604.14	1.52	130	0.80
P-2580_SPL6(2)	J57102	J-3065	2000	231.8	411604.14	1.52	130	0.80
P57127	J57122	J57123	300	397.3	3187.20	0.52	130	1.01
P57126	J57121	J57122	300	625.2	3187.20	0.52	130	1.01
P57125	J57120	J57121	300	690.3	7443.20	1.22	130	4.88
P57124	J57119	J57120	400	890.8	7443.20	0.69	130	1.20
P57129	J5586	J57127	400	9.4	21934.40	2.02	130	8.89
P57131	J-151	J-72	250	5.8	0.00	0.00	130	0.00
P-2122	J-133	J-136	250	10.3	0.00	0.00	130	0.00
P57137	J-1634	J63082	250	13.5	4938.61	1.16	130	5.54
P63084	J-3118	J63084	300	43.6	3009.60	0.49	130	0.91
P-1086_SPL1	J-334	J63083	800	751.9	24890.37	0.57	130	0.38
P-1086_SPL2	J63083	J-1940	800	662.3	24890.37	0.57	130	0.38
P63087	J63085	J-2612	400	15.8	12648.00	1.16	130	3.21
P63086	J36701	J63086	400	5.4	14958.40	1.38	130	4.37
P63088	J-803	J64893	400	3.3	11904.00	1.10	130	2.86
P64902	J-3118	J57107	800	40.7	99483.47	2.29	130	4.99
P57111_SPL1	J57105	J64901	2000	63.1	290508.91	1.07	130	0.42
P57111_SPL3	J64902	J57106	1800	223.8	290508.91	1.32	130	0.70
P57130	J-839	J-2204	250	4.8	0.00	0.00	130	0.00
P57132	J31286	J31287	225	4.4	0.00	0.00	130	0.00
P-14(2)	J-3220	J-3219	500	940.9	0.00	0.00	130	0.00
P-14(1)(2)	J64903	J-3220	500	1388.4	0.00	0.00	130	0.00
P-64911	J-64909	J-64910	300	254.4	0.00	0.00	130	0.00
P-64919	J-3074	J-64917	1600	563.9	191025.45	1.10	130	0.57
P-64910	J-64908	J-64909	300	601.1	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-64914	J-64912	J-64913	600	758.6	13078.22	0.54	130	0.47
P-64908	J-3036	J-64907	500	1555.3	4972.42	0.29	130	0.19
P-64913	J-1412	J-64912	600	1598.2	13078.22	0.54	130	0.47
P-64916	J-3097	J-64915	1400	2734.2	149557.98	1.12	130	0.70
P-64909	J-64907	J-64908	500	3910.7	4972.42	0.29	130	0.19
P-64907	J-64906	J-3008	400	4150.2	4872.27	0.45	130	0.55
P-64905	J-2911	J-64905	1400	8766.6	230143.78	1.73	130	1.55
P-64912	J-64908	J-64911	500	9194.2	4972.42	0.29	130	0.19
P-269(1)	J-3122	J-64911	300	2477.7	4972.42	0.81	130	2.31
P-269(2)	J-64911	J-3125	300	1624.1	0.00	0.00	130	0.00
P-1310(1)	J-3062	J-64906	400	3006.2	2265.87	0.21	130	0.13
P-1310(2)	J-64906	J-3040	300	1478.1	2606.40	0.43	130	0.70
P64897(1)	J64894	J-64917	1600	57.4	191025.45	1.10	130	0.57
P-2370_SPL4(1)	J21563	J-64913	500	307.2	10465.46	0.62	130	0.76
P-2370_SPL4(2)	J-64913	J-2908	600	1608.0	21722.75	0.89	130	1.21
P-2193_SPL3(1)	J54278	J-64918	700	681.9	38244.00	1.15	130	1.63
P-2193_SPL3(2)	J-64918	J54275	700	4961.7	36644.00	1.10	130	1.51
P57102	J54275	J54276	600	3497.7	0.00	0.00	130	0.00
P-64922	J-64920	J-64921	2000	280.9	411604.14	1.52	130	0.80
P-64920	J64900	J-64919	2000	467.7	411604.14	1.52	130	0.80
P-64921	J63079	J-64920	2000	472.8	411604.14	1.52	130	0.80
P57133(2)	J-64919	J63079	2000	344.5	411604.14	1.52	130	0.80
P-64927	J-3074	J-64915	1400	330.9	162947.35	1.23	130	0.82
P-2477(2)	J-3217	J-3101	600	10.8	0.00	0.00	130	0.00
P-64928	J57123	J-64925	300	483.7	3187.20	0.52	130	1.01
P-64929	J-64925	J-64926	300	650.5	3187.20	0.52	130	1.01
P-64930	J-64926	J-64927	300	898.5	3187.20	0.52	130	1.01
P-21	J-3119	J47823	300	23.9	1806.27	0.30	130	0.35
P-64932	J-64928	J-64929	250	5.4	2635.38	0.62	130	1.73
P-64933	J-64930	J-64929	300	18.4	2635.38	0.43	130	0.71
P-441(1)	J-2484	J-64928	250	385.0	857.83	0.20	130	0.22
P-441(2)	J-64928	J-2689	250	7.5	2521.44	0.59	130	1.60
P-1268(1)	J-2841	J-64930	600	482.6	13888.80	0.57	130	0.53
P-1268(2)	J-64930	J-3119	600	513.1	12225.19	0.50	130	0.42
P-64934	J-64931	J-64932	300	35.2	716.89	0.12	130	0.06
P-900(2)	J-64931	J-2841	800	539.6	13888.80	0.32	130	0.13
P-64938	J-64937	J-64936	250	29.9	1889.09	0.45	130	0.93
P-64939	J-64933	J-64935	300	32.5	2315.20	0.38	130	0.56
P-64937	J-64934	J-64937	300	37.7	1889.09	0.31	130	0.38
P-691(1)	J-2472	J-64935	300	12.5	1431.73	0.23	130	0.23
P-900(1)(1)(1)	J-309	J-64934	800	940.5	19015.89	0.44	130	0.23
P-900(1)(1)(2)	J-64934	J-64933	800	9.2	17126.81	0.39	130	0.19
P-646(1)	J-2516	J-64936	250	157.3	1031.26	0.24	130	0.30

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-646(2)	J-64936	J-2505	250	5.6	857.83	0.20	130	0.22
P-64940	J-64938	J-64939	300	34.0	221.87	0.04	130	0.01
P-691(2)(1)	J-64935	J-64939	300	292.5	883.47	0.14	130	0.09
P-691(2)(2)	J-64939	J-1892	300	18.5	1089.39	0.18	130	0.14
P-900(1)(2)(1)	J-64933	J-64938	800	310.5	14811.60	0.34	130	0.15
P-900(1)(2)(2)	J-64938	J-64931	800	688.0	14605.69	0.34	130	0.14
P-64941	J-282	J-64941	250	0.9	0.00	0.00	130	0.00
P-64943	J-64942	J-64943	250	1.0	0.00	0.00	130	0.00
P-64946	J-64945	J-64946	250	1.5	0.00	0.00	130	0.00
P-64942	J-64941	J-64942	250	45.8	0.00	0.00	130	0.00
P-64945	J-64944	J-64945	250	142.2	0.00	0.00	130	0.00
P-64944	J-64943	J-64944	250	356.1	0.00	0.00	130	0.00
P-64947	J-64946	J56917	250	434.2	0.00	0.00	130	0.00
P-64951	J-64950	J-64951	300	4.2	8508.03	1.39	130	6.25
P-64953	J-64950	J-64951	300	7.1	6370.32	1.04	130	3.65
P-64952	J-64951	J-64949	300	5.8	14878.34	2.44	130	17.58
P-64950	J-64948	J-64950	300	11.3	14878.34	2.44	130	17.58
P-64954	J-447	J-64953	300	27.5	0.00	0.00	130	0.00
P-1959(1)	J-600	J-64949	300	315.0	10123.15	1.66	130	8.62
P-1959(2)	J-64949	J-2571	300	397.5	4755.20	0.78	130	2.13
P-2133(2)(1)	J-64947	J-64948	600	937.5	20700.75	0.85	130	1.11
P-2133(2)(2)(1)	J-64948	J-64952	600	429.8	5822.41	0.24	130	0.11
P-2133(2)(2)(2)	J-64952	J-2787	500	459.0	5822.41	0.34	130	0.26
P-2384(1)	J-2818	J-64954	800	465.8	52680.29	1.21	130	1.54
P-2384(2)	J-64954	J-1698	600	450.5	52680.29	2.16	130	6.25
P-22	J-2818	J-2582	250	20.2	5958.38	1.40	130	7.85
P-64957	J-64955	J-64956	300	30.1	0.00	0.00	130	0.00
P-64956	J-2844	J-64955	300	1547.6	0.00	0.00	130	0.00
P-2545(1)	J-2861	J-1246	1200	423.8	128237.22	1.31	130	1.11
P-2545(2)	J-1246	J-184	1000	80.9	74316.64	1.10	130	0.98
P-23	J-184	J-309	800	19.5	43649.58	1.01	130	1.09
P-1965(1)	J-2464	J-64953	300	104.8	4755.19	0.78	130	2.13
P-1965(2)	J-64953	J-448	300	33.5	4755.19	0.78	130	2.13
P-24	J-1639	J-2942	400	3.8	24998.66	2.30	130	11.32
P-25	J-1478	J48176	250	8.3	0.00	0.00	130	0.00
P-26	J51512	J-3217	300	11.5	0.00	0.00	130	0.00
J-64961	J-3218	J-64957	400	5.0	649.19	0.06	130	0.01
P-45	J-64958	J-3216	500	1293.3	17019.27	1.00	130	1.87
P-46	J-2934	J-64958	400	2534.2	9126.32	0.84	130	1.75
P-47	J-3216	J-3217	600	1291.0	14311.89	0.59	130	0.56
P-48	J57105	J57110	400	40.0	12648.00	1.16	130	3.21
P63090(2)	J-39	J64894	1600	2201.8	191025.45	1.10	130	0.57
P-54	J-3154	J-41	2000	296.2	303156.91	1.12	130	0.45

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-55	J-41	J-42	2000	625.0	303156.91	1.12	130	0.45
P-56	J-42	J-43	2000	553.7	303156.91	1.12	130	0.45
P-57	J-43	J-44	2000	382.0	303156.91	1.12	130	0.45
P-58	J-44	J-45	2000	1373.2	303156.91	1.12	130	0.45
P57110(2)	J-46	J57105	2000	250.9	303156.91	1.12	130	0.45
P-59	J-45	J-46	2000	539.0	303156.91	1.12	130	0.45
P22329	J22900	J22901	250	0.4	212.61	0.05	130	0.02
P42498	J-940	J-1209	250	86.7	0.00	0.00	130	0.00
P42496	J-2199	J-940	300	115.2	0.00	0.00	130	0.00
P48187	J-49	J50377	300	0.5	4039.43	0.66	130	1.57
P48188	J50377	J-391	300	224.3	4039.43	0.66	130	1.57
P50380	J-2561	J-2702	500	1164.8	18201.39	1.07	130	2.12
P42497	J-1209	J-1967	250	201.6	0.00	0.00	130	0.00
P42502	J43796	J43798	300	1.4	3454.93	0.57	130	1.18
P42499	J-1049	J43796	300	43.3	3454.93	0.57	130	1.18
P42500	J43798	J-674	300	167.7	3454.93	0.57	130	1.18
P42476	J-2831	J-1069	500	1.1	38591.84	2.27	130	8.53
P42531	J46759	J-2101	300	1.9	0.00	0.00	130	0.00
P50379	J-777	J-1515	200	5.4	0.00	0.00	130	0.00
P50394	J51495	J51493	250	6.0	3889.60	0.92	130	3.56
P42511	J45417	J-2105	250	9.3	1771.97	0.42	130	0.83
P50392	J51493	J-1723	250	18.9	3889.60	0.92	130	3.56
P42516	J-1754	J-1755	250	17.0	1771.97	0.42	130	0.83
P50391	J-1722	J51495	250	23.7	3889.60	0.92	130	3.56
P42503	J-1755	J-2008	250	34.2	1771.97	0.42	130	0.83
P42514	J-2008	J-2009	250	37.8	1771.97	0.42	130	0.83
P42518	J-2104	J45417	250	38.4	1771.97	0.42	130	0.83
P42515	J-2009	J-2133	250	45.1	1771.97	0.42	130	0.83
P42524	J-2100	J-2101	300	49.6	0.00	0.00	130	0.00
P42520	J-2247	J-2248	250	65.6	1771.97	0.42	130	0.83
P42505	J-2292	J-2293	300	70.5	1771.97	0.29	130	0.34
P28756	J-2208	J31282	300	73.3	0.01	0.00	130	0.00
P42507	J-2339	J-2104	250	93.9	1771.97	0.42	130	0.83
P42508	J-2133	J-2339	250	94.5	1771.97	0.42	130	0.83
P42527	J46759	J-2371	300	96.6	0.00	0.00	130	0.00
P28755	J31282	J-794	300	97.3	0.01	0.00	130	0.00
P42513	J-2248	J-1754	250	124.1	1771.97	0.42	130	0.83
P42475	J-1831	J-2831	500	136.4	20764.75	1.22	130	2.71
P42504	J-1035	J-2292	300	160.2	1771.97	0.29	130	0.34
P42525	J-2530	J-2100	300	162.5	0.00	0.00	130	0.00
P23642	J-925	J28570	300	162.8	0.01	0.00	130	0.00
P42509	J-2279	J-2471	250	178.6	1771.97	0.42	130	0.83
P42526	J-2625	J46715	300	195.2	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P42528	J46715	J-554	300	218.9	0.00	0.00	130	0.00
P42474	J-2050	J-1831	500	230.3	20764.75	1.22	130	2.71
P42522	J-2371	J-2625	300	252.3	0.00	0.00	130	0.00
P42510	J-950	J-2247	250	303.9	1771.97	0.42	130	0.83
P48180	J-773	J-1686	500	818.5	45108.94	2.66	130	11.39
P42477	J-2049	J-1111	500	932.0	17251.80	1.02	130	1.92
P54346	J57008	J57007	300	0.4	0.00	0.00	130	0.00
P54327	J56908	J56909	250	1.2	0.00	0.00	130	0.00
P54329	J56995	J56996	300	1.8	0.00	0.00	130	0.00
P54348	J57007	J57006	300	1.8	0.00	0.00	130	0.00
P54316	J56820	J56821	300	1.8	0.01	0.00	130	0.00
P20483	J21541	J21542	225	2.8	10212.80	2.97	130	35.57
P54365	J56911	J56912	250	2.9	0.00	0.00	130	0.00
P20485	J21542	J21544	225	4.5	10212.80	2.97	130	35.57
P54351	J57026	J57027	250	3.6	0.00	0.00	130	0.00
P54399	J56831	J56830	300	4.3	0.01	0.00	130	0.00
P54368	J57011	J57013	250	4.7	0.00	0.00	130	0.00
P54369	J56867	J56868	250	5.4	0.00	0.00	130	0.00
P54354	J56958	J56959	250	5.8	0.00	0.00	130	0.00
P54308	J56912	J56913	250	6.7	0.00	0.00	130	0.00
P54333	J56915	J56916	300	7.2	0.01	0.00	130	0.00
P54376	J56909	J56911	250	8.7	0.00	0.00	130	0.00
P54362	J56955	J56958	250	9.0	0.00	0.00	130	0.00
P54342	J56954	J56955	250	9.3	0.00	0.00	130	0.00
P54355	J56913	J56914	250	10.7	0.00	0.00	130	0.00
P54396	J56916	J56918	300	10.9	0.01	0.00	130	0.00
P54397_SPL1	J57006	J57093	300	11.2	0.00	0.00	130	0.00
P54331	J56889	J56894	250	14.8	0.01	0.00	130	0.00
P54307	J56950	J56952	250	21.6	0.00	0.00	130	0.00
P54298	J56923	J56924	250	28.6	0.01	0.00	130	0.00
P54363	J56982	J56983	250	29.3	0.00	0.00	130	0.00
P54398	J56972	J56970	300	32.3	0.00	0.00	130	0.00
P54300	J56885	J56889	250	32.7	0.00	0.00	130	0.00
P54296	J56986	J56990	250	32.8	0.00	0.00	130	0.00
P54371	J56991	J56990	250	35.4	0.00	0.00	130	0.00
P54397_SPL2	J57093	J57005	300	36.9	0.00	0.00	130	0.00
P54407	J56821	J56825	300	37.0	0.01	0.00	130	0.00
P54375	J56879	J56876	250	39.3	0.01	0.00	130	0.00
P54352	J56991	J56993	250	40.3	0.00	0.00	130	0.00
P54347	J56979	J56981	300	45.0	0.00	0.00	130	0.00
P54322	J56866	J56870	300	47.6	0.01	0.00	130	0.00
P54372	J56993	J56994	250	50.6	0.00	0.00	130	0.00
P54345	J56897	J56901	300	52.3	0.01	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P54325	J56865	J56867	250	53.3	0.01	0.00	130	0.00
P54320	J56858	J56860	300	54.5	0.01	0.00	130	0.00
P54356	J56842	J56852	250	56.6	0.01	0.00	130	0.00
P54374	J56879	J56885	250	59.7	0.00	0.00	130	0.00
P54309	J-231	J56789	300	65.8	0.01	0.00	130	0.00
P54319	J56853	J56858	300	66.2	0.01	0.00	130	0.00
P42517	J-387	J-1034	300	68.2	1771.97	0.29	130	0.34
P54310	J56905	J56908	250	68.8	0.01	0.00	130	0.00
P54358	J-571	J56796	250	91.5	0.01	0.00	130	0.00
P54313	J56789	J56793	300	78.5	0.01	0.00	130	0.00
P54297	J56983	J56986	250	80.9	0.00	0.00	130	0.00
P54286	J56977	J56979	300	81.1	0.00	0.00	130	0.00
P54343	J56996	J56997	300	81.9	0.00	0.00	130	0.00
P54318	J56812	J56815	300	83.7	0.01	0.00	130	0.00
P54314	J56803	J56812	300	85.9	0.01	0.00	130	0.00
P54379	J56870	J56878	300	91.2	0.01	0.00	130	0.00
P54312	J56793	J56803	300	92.0	0.01	0.00	130	0.00
P54285	J56838	J56831	300	97.1	0.01	0.00	130	0.00
P54366	J56868	J56876	250	100.8	0.00	0.00	130	0.00
P54301	J56952	J56954	250	102.1	0.00	0.00	130	0.00
P54315	J56833	J56835	250	102.6	0.01	0.00	130	0.00
P54317	J56815	J56820	300	103.1	0.01	0.00	130	0.00
P54324	J56835	J56837	250	109.5	0.01	0.00	130	0.00
P54332	J56894	J56905	250	115.4	0.01	0.00	130	0.00
P54370	J56960	J56964	250	126.7	0.00	0.00	130	0.00
P54302	J56860	J56866	300	133.4	0.01	0.00	130	0.00
P54328	J57013	J57026	250	141.9	0.00	0.00	130	0.00
P54373	J57002	J57011	250	145.5	0.00	0.00	130	0.00
P54287	J56830	J56825	300	147.8	0.01	0.00	130	0.00
P54361	J56981	J56984	300	152.9	0.00	0.00	130	0.00
P54360	J56968	J56973	250	154.2	0.00	0.00	130	0.00
P54405	J56878	J56897	300	154.9	0.01	0.00	130	0.00
P54389	J57003	J57008	300	158.9	0.00	0.00	130	0.00
P54284	J56997	J57003	300	172.9	0.00	0.00	130	0.00
P54299	J56914	J56920	250	177.5	0.00	0.00	130	0.00
P54326	J56837	J56842	250	179.9	0.01	0.00	130	0.00
P54321	J56838	J56853	300	221.1	0.01	0.00	130	0.00
P54323	J56852	J56865	250	224.5	0.01	0.00	130	0.00
P54406	J56972	J56977	300	229.0	0.00	0.00	130	0.00
P54353	J56984	J56995	300	251.3	0.00	0.00	130	0.00
P54367	J56994	J57001	250	263.8	0.00	0.00	130	0.00
P54344	J56949	J56961	300	271.0	0.00	0.00	130	0.00
P54330	J56901	J56915	300	330.5	0.01	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P54311	J56973	J56982	250	349.8	0.00	0.00	130	0.00
P54364	J56964	J56968	250	366.0	0.00	0.00	130	0.00
P54357	J56796	J56833	250	443.1	0.01	0.00	130	0.00
P54378	J56919	J56949	300	482.1	0.00	0.00	130	0.00
P54282	J56925	J56950	250	499.0	0.00	0.00	120	0.00
P54304	J56961	J56970	300	520.9	0.00	0.00	130	0.00
P46766	J-2109	J-1860	400	656.2	10108.55	0.93	130	2.12
P23643	J28570	J-2180	300	0.4	0.01	0.00	130	0.00
P54349	J57000	J56999	300	0.9	0.00	0.00	130	0.00
P23637	J-2513	J28576	300	1.4	0.01	0.00	130	0.00
P54335	J57005	J57004	300	2.7	0.00	0.00	130	0.00
P54387	J56988	J56989	300	3.3	0.00	0.00	130	0.00
P54350	J56987	J56985	300	4.2	0.00	0.00	130	0.00
P46769	J47792	J47791	250	4.5	6715.20	1.58	130	9.79
P42521	J45348	J-2471	250	4.8	1771.97	0.42	130	0.83
P42488_SPL1	J-1804	J-2798	500	5.9	0.00	0.00	130	0.00
P46768	J47791	J-1385	250	6.3	6715.20	1.58	130	9.79
P54339	J57059	J57056	300	10.4	0.00	0.00	130	0.00
P20482	J-1524	J21541	225	11.1	10212.80	2.97	130	35.57
P23638	J-2513	J-1658	300	17.6	0.01	0.00	130	0.00
P46764	J-2109	J47792	250	31.9	6715.20	1.58	130	9.79
P42493	J-1446	J-209	500	45.5	17390.00	1.03	130	1.95
P54303	J57062	J57059	300	45.9	0.00	0.00	130	0.00
P46762	J-1385	J-894	250	73.3	0.00	0.00	130	0.00
P42506	J-2307	J-2308	250	90.2	1771.97	0.42	130	0.83
P54305	J57004	J57000	300	97.2	0.00	0.00	130	0.00
P42519	J45348	J-2307	250	133.8	1771.97	0.42	130	0.83
P42512	J-2293	J-2152	250	153.9	1771.97	0.42	130	0.83
P23613	J28576	J-916	300	160.3	0.01	0.00	130	0.00
P54338	J56998	J57032	300	177.3	0.00	0.00	130	0.00
P42490	J-2526	J-1821	500	166.0	20925.52	1.23	130	2.75
P54337	J57056	J57032	300	183.0	0.00	0.00	130	0.00
P54394	J56989	J56998	300	208.4	0.00	0.00	130	0.00
P54388	J56985	J56988	300	227.4	0.00	0.00	130	0.00
P42495	J-208	J-2629	500	218.7	17390.00	1.03	130	1.95
P42494	J-2629	J-891	500	278.2	17390.00	1.03	130	1.95
P54390	J56999	J56987	300	288.7	0.00	0.00	130	0.00
P42492	J-1835	J-955	250	352.6	0.00	0.00	130	0.00
P42491	J-2674	J-2679	500	354.1	20925.52	1.23	130	2.75
P23622	J-2553	J-2141	300	449.0	0.01	0.00	130	0.00
P42489	J-2679	J-1240	500	711.9	20925.52	1.23	130	2.75
P42488_SPL2	J-2798	J-1769	500	833.3	31253.67	1.84	130	5.77
P42487	J-1639	J-2526	500	855.2	20925.52	1.23	130	2.75

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m³/day)	V (m/s)	C	I (‰)
P54393	J57087	J-211	250	0.9	955.99	0.23	130	0.26
P54281	J57092	J57091	400	1.3	0.00	0.00	120	0.00
P54290	J57058	J57057	300	1.6	0.00	0.00	130	0.00
P54385	J57090	J57092	400	2.1	0.00	0.00	130	0.00
P54402	J57030	J57031	250	2.7	0.00	0.00	130	0.00
P54294	J57038	J57037	300	4.2	0.00	0.00	130	0.00
P54295_SPL2	J21550	J57012	300	4.6	0.00	0.00	130	0.00
P54395	J57055	J57052	300	5.2	0.00	0.00	130	0.00
P54380	J57075	J57074	250	9.3	955.99	0.23	130	0.26
P54288	J57055	J57057	300	10.4	0.00	0.00	130	0.00
P54403	J57060	J57058	300	10.5	0.00	0.00	130	0.00
P51526	J54272	J54273	250	10.9	0.00	0.00	130	0.00
P54336	J57027	J57030	250	11.6	0.00	0.00	130	0.00
P51520	J51517	J51518	250	12.1	0.00	0.00	130	0.00
P54386	J57091	J-211	400	13.6	0.00	0.00	130	0.00
P54382	J57092	J57081	300	13.7	0.00	0.00	130	0.00
P51521	J51518	J51519	250	16.1	0.00	0.00	130	0.00
P54295_SPL3	J21549	J21550	300	20.3	0.00	0.00	130	0.00
P51536	J54273	J54274	250	16.9	0.00	0.00	130	0.00
P54289	J57050	J57052	300	19.3	0.00	0.00	130	0.00
P51522	J51519	J51520	250	29.7	0.00	0.00	130	0.00
P54341	J57074	J57087	250	44.6	955.99	0.23	130	0.26
P51534	J51522	J54259	250	45.9	0.00	0.00	130	0.00
P54400	J57081	J57062	300	47.2	0.00	0.00	130	0.00
P46765	J-2306	J-1158	400	82.1	16827.97	1.55	130	5.44
P51524	J51521	J51522	250	84.6	0.00	0.00	130	0.00
P51525	J54272	J54269	250	98.0	0.00	0.00	130	0.00
P54292	J57050	J57038	300	99.3	0.00	0.00	130	0.00
P46774	J-2394	J-2395	250	109.3	2685.45	0.63	130	1.79
P54295_SPL1	J57037	J21549	300	140.1	0.00	0.00	130	0.00
P54340	J57066	J57075	250	204.3	0.00	0.00	130	0.00
P51533	J54260	J54269	250	333.3	0.00	0.00	130	0.00
P42530_SPL1	J46464	J-2796	300	365.4	0.00	0.00	130	0.00
P51523	J51520	J51521	250	397.6	0.00	0.00	130	0.00
P46767	J-1158	J-2109	400	453.2	12435.55	1.15	130	3.11
P46772	J-1637	J-2394	300	471.8	2685.45	0.44	130	0.74
P46771	J-2395	J-2414	250	500.6	2685.45	0.63	130	1.79
P42530_SPL2	J-2796	J-1281	300	511.1	3052.89	0.50	130	0.94
P54306	J57031	J57066	250	532.5	0.00	0.00	130	0.00
P46763	J-1793	J-2306	400	544.9	16827.97	1.55	130	5.44
P42529	J-1780	J-555	300	722.4	0.00	0.00	130	0.00
P46773	J-2456	J-1476	300	967.0	2685.45	0.44	130	0.74
P42523	J-1338	J46464	300	1049.2	0.00	0.00	130	0.00

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P23615	J-2451	J28604	300	3.7	0.01	0.00	130	0.00
P54381	J57072	J57078	400	9.5	0.00	0.00	130	0.00
P54293	J57063	J57068	300	11.7	0.00	0.00	130	0.00
P54384	J57065	J57072	400	12.1	0.00	0.00	130	0.00
P54291	J57061	J57063	300	31.3	0.00	0.00	130	0.00
P54401	J57072	J57069	300	46.8	0.00	0.00	130	0.00
P54283	J57065	J57064	300	46.1	0.00	0.00	130	0.00
P54404	J57061	J57060	300	6.0	0.00	0.00	130	0.00
P54383	J57078	J57090	400	36.9	0.00	0.00	130	0.00
P54392	J57064	J57063	300	83.3	0.00	0.00	130	0.00
P54391	J57069	J57068	300	84.0	0.00	0.00	130	0.00
P54334	J-602	J57075	250	3.4	955.99	0.23	130	0.27
P42480	J-2029	J-1493	500	32.4	6330.34	0.37	130	0.30
P42484	J-1570	J-1437	500	37.3	27299.43	1.61	130	4.49
P42478	J-1303	J-1698	500	107.8	28369.36	1.67	130	4.83
P42482	J-262	J-1303	500	478.8	22340.56	1.32	130	3.10
P42483	J-1698	J-1570	500	502.3	27299.43	1.61	130	4.49
P46780	J47823	J-2715	300	11.1	0.00	0.00	130	0.00
P46779	J47861	J-252	300	37.1	1089.39	0.18	130	0.14
P46777	J-1891	J47861	300	397.6	1089.39	0.18	130	0.14
P46776	J-2714	J47823	300	638.4	1806.28	0.30	130	0.35
P46778(1)	J-2609	J-64932	300	17.7	1089.39	0.18	130	0.14
P46778(2)	J-64932	J-2714	300	855.9	1806.28	0.30	130	0.35
P23614	J28611	J-191	300	3.7	0.01	0.00	130	0.00
P42481_SPL2	J-2821	J-923	500	4.1	6330.34	0.37	130	0.30
P42479	J-726	J-1403	250	9.6	3955.18	0.93	130	3.67
P23624_SPL2	J-2003	J-2004	300	31.3	0.00	0.00	130	0.00
P23624_SPL4	J-2004	J-2119	300	46.1	0.00	0.00	130	0.00
P23626_SPL1	J28604	J-2452	300	129.1	0.01	0.00	130	0.00
P23624_SPL1	J-191	J-2003	300	294.5	0.00	0.00	130	0.00
P23641	J-2694	J-1990	300	407.4	0.00	0.00	130	0.00
P42481_SPL1	J-2029	J-2821	500	540.9	6330.34	0.37	130	0.30
P23626_SPL2	J-2452	J28611	300	576.2	0.01	0.00	130	0.00
P42486	J-1803	J-1566	400	1342.2	11852.20	1.09	130	2.84
P22335	J22902	J22900	250	1.3	212.61	0.05	130	0.01
P23608	J-868	J-869	1000	8.3	62365.73	0.92	130	0.71
P22336	J-321	J22902	250	13.6	2644.54	0.62	130	1.74
P23605	J-541	J-1307	1000	129.7	53711.22	0.79	130	0.54
P23610	J-289	J-2660	1000	290.5	63442.94	0.93	130	0.73
P23604	J-1307	J-2672	1000	466.7	34865.76	0.51	130	0.24
P23606	J-542	J-655	1000	541.2	56385.85	0.83	130	0.59
P23607	J-2660	J-2888	1000	604.5	63442.94	0.93	130	0.73
P41934	J-2019	J-2712	400	673.5	9955.75	0.92	130	2.06

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P23609	J-1573	J-2405	1000	861.5	62365.73	0.92	130	0.71
P23639	J28667	J-363	300	0.2	0.00	0.00	130	0.00
P23620	J-362	J28667	300	2.9	0.00	0.00	130	0.00
P23619	J-363	J-1205	300	11.2	0.00	0.00	130	0.00
P22334	J22859	J22902	225	337.6	2729.11	0.79	130	3.09
P23640	J-1991	J-362	300	555.5	0.00	0.00	130	0.00
P22331	J22901	J22903	160	1.3	212.61	0.12	130	0.14
P22332	J22938	J-1664	160	173.3	212.61	0.12	130	0.14
P22333	J22920	J22938	160	185.6	212.61	0.12	130	0.14
P22330	J22903	J22920	160	263.0	212.61	0.12	130	0.14
P54359	J56917	J56918	300	1.9	0.01	0.00	130	0.00
P54377	J56919	J56917	300	1.9	0.01	0.00	130	0.00
P31291_SPL1	J33963	J33964	300	5.1	25689.60	4.21	130	48.35
P31290	J33964	J33963	300	7.6	0.00	0.00	130	0.00
P51535	J54259	J54260	250	5.5	0.00	0.00	130	0.00
P31291_SPL2	J33964	J31289	300	10.8	25689.60	4.21	130	48.35
P23634	J-1237	J28674	250	2.5	0.00	0.00	130	0.00
P50395	J-52	J-51(1)	225	5.2	0.00	0.00	130	0.00
P23618_SPL2	J-1280	J-649	250	6.9	0.00	0.00	130	0.00
P23636	J-1205	J-1371	250	11.9	0.00	0.00	130	0.00
P23635	J-1371	J-52	250	16.2	0.00	0.00	130	0.00
P23618_SPL1	J-2628	J-1280	250	403.1	0.00	0.00	130	0.00
P23633	J28674	J-2627	250	584.2	0.00	0.00	130	0.00
P23616	J-2685	J28699	250	0.6	0.00	0.00	130	0.00
P23617	J28701	J28702	250	1.0	0.00	0.00	130	0.00
P23631_SPL1	J-2612	J-2783	250	8.3	0.00	0.00	130	0.00
P23630_SPL2	J31284	J31285	250	19.9	0.00	0.00	130	0.00
P23630_SPL1	J28699	J31284	250	110.2	0.00	0.00	130	0.00
P23630_SPL4	J31285	J28701	250	191.4	0.00	0.00	130	0.00
P23631_SPL2	J-2783	J-2613	250	227.4	0.00	0.00	130	0.00
P23625	J28702	J-2612	250	258.5	0.00	0.00	130	0.00
P23623	J-650	J-2685	250	373.7	0.00	0.00	130	0.00
P23632	J-2613	J-2038	250	411.7	0.00	0.00	130	0.00
P23629	J28751	J28752	250	3.7	0.00	0.00	130	0.00
P23612	J28744	J28745	250	12.6	0.00	0.00	130	0.00
P23645	J28722	J28726	250	69.3	0.00	0.00	130	0.00
P23628	J28752	J28753	250	190.0	0.00	0.00	130	0.00
P23646	J-1977	J28722	250	194.0	0.00	0.00	130	0.00
P23644	J28745	J28750	250	360.2	0.00	0.00	130	0.00
P23627	J28753	J-2856	250	499.2	0.00	0.00	130	0.00
P23611	J28726	J28744	250	533.6	0.00	0.00	130	0.00
P14543	J16596	J16593	600	4.4	24803.23	1.02	130	1.55
P18616	J16400	J20479	300	8.5	13013.36	2.13	130	13.72

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P16765_SPL2	J-3020	J17841	2000	46.6	342775.73	1.26	130	0.57
P16767_SPL2	J-3089	J17417	2000	56.5	310006.00	1.14	130	0.47
P-2778_SPL1	J-3194	J41932	600	65.0	40832.01	1.67	130	3.90
P16772	J18614	J-2885	2000	178.4	358135.73	1.32	130	0.62
P14553	J16593	J16400	600	415.0	24803.23	1.02	130	1.55
P16770	J17841	J17753	2000	462.7	342775.73	1.26	130	0.57
P-2605	J-2864	J-3191	1200	612.0	133240.12	1.36	130	1.19
P16767_SPL1	J17532	J-3089	2000	715.5	328499.98	1.21	130	0.53
P16768_SPL1	J17679	J-3025	2000	748.9	342775.73	1.26	130	0.57
P14544	J16400	J16533	600	774.4	34636.88	1.42	130	2.87
P16769	J17753	J17706	2000	802.4	342775.73	1.26	130	0.57
P16771	J17706	J17679	2000	865.3	342775.73	1.26	130	0.57
P16768_SPL2	J-3025	J17532	2000	935.3	341513.36	1.26	130	0.57
P-115	J-2826	J-2827	500	1580.7	28833.00	1.70	130	4.97
P16765_SPL1	J18614	J-3020	2000	3125.1	358135.73	1.32	130	0.62
P-2544	J-3191	J-2826	1200	3001.1	124644.93	1.28	130	1.05
P-2864	J-2864	J-3194	600	3467.3	51114.70	2.09	130	5.91
P-2771(1)	J-2863	J-64905	1400	36.7	0.00	0.00	130	0.00
P-2771(2)	J-64905	J-2864	1400	2225.5	230143.78	1.73	130	1.55
P-20_SPL1	J-1174	J11173	800	4.5	53920.58	1.24	130	1.61
P-1050_SPL2	J21853	J-3151	300	10.5	2934.26	0.48	130	0.87
P-2318	J-3212	J-3214	300	10.7	5857.71	0.96	130	3.13
P-20_SPL2	J11173	J-1246	800	39.8	53920.58	1.24	130	1.61
P-1095	J-613	J-1174	800	37.1	41150.98	0.95	130	0.97
P5589_SPL1	J5580	J11168	600	56.4	10840.01	0.44	130	0.33
P-2111_SPL2	J1	J-3106	600	57.8	18513.76	0.76	130	0.90
P18618_SPL2	J-2863	J-2836	2000	101.4	310006.00	1.14	130	0.47
P-2321	J-3210	J-2790	300	239.8	5857.71	0.96	130	3.13
P-211_SPL1	J-2802	J21566	250	299.1	0.00	0.00	130	0.00
P-2683	J-2845	J-3169	800	348.3	51320.92	1.18	130	1.47
P41937_SPL4	J-3167	J20481	800	348.5	48232.08	1.11	130	1.31
P-2232	J-3151	J-3046	300	375.1	5335.59	0.87	130	2.63
P-2323	J-3214	J-3210	300	382.5	5857.71	0.96	130	3.13
P-1919_SPL1	J-184	J14542	800	288.5	30667.06	0.71	130	0.56
P-1678	J-2833	J-3118	600	473.7	9966.17	0.41	130	0.29
P41937_SPL1	J-2785	J-3165	800	492.6	54693.56	1.26	130	1.65
P-2632	J-3169	J-3171	800	506.2	47168.91	1.09	130	1.25
P-2858	J-2837	J-2800	600	590.7	49936.23	2.04	130	5.66
P-2594_SPL1	J-3171	J20480	800	607.6	42423.32	0.98	130	1.03
P-275_SPL2	J22307	J-3052	300	618.2	746.01	0.12	130	0.07
P-1213	J-1870	J-2857	600	622.1	9593.32	0.39	130	0.27
P-1628	J-2857	J-3106	600	629.7	19078.89	0.78	130	0.95
P-2859	J-2886	J-1548	600	708.8	49936.23	2.04	130	5.66

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2912	J-2794	J-720	600	719.9	42423.32	1.74	130	4.18
P-275_SPL1	J-3046	J22307	300	740.2	5335.59	0.87	130	2.63
P18618_SPL1	J17417	J-2863	2000	818.4	310006.00	1.14	130	0.47
P-2062_SPL1	J-2867	J14112	300	837.4	649.19	0.11	130	0.05
P41937_SPL2	J-3165	J-3167	800	845.5	51462.82	1.18	130	1.47
P-2860	J-2800	J-2886	600	871.0	49936.23	2.04	130	5.66
P-1050_SPL1	J-2876	J21853	300	928.6	2934.26	0.48	130	0.87
P-73	J-2800	J-2801	400	967.8	0.00	0.00	130	0.00
P5589_SPL2	J11168	J11163	600	1312.9	10840.01	0.44	130	0.33
P-2061	J-64957	J-2867	300	1458.1	649.19	0.11	130	0.05
P-1915	J-2810	J-1870	600	1464.4	10937.29	0.45	130	0.34
P-2861	J-2911	J-2837	600	1718.7	49936.23	2.04	130	5.66
P-2062_SPL2	J14112	J-2808	300	1551.7	649.19	0.11	130	0.05
P-272	J-2837	J-2838	300	1594.1	0.00	0.00	130	0.00
P-2388	J-1548	J-2812	600	1928.1	23595.80	0.97	130	1.41
P-2351	J-2826	J-2954	1200	2265.2	75244.15	0.77	130	0.41
P-2618	J-2845	J-2785	600	2156.4	23923.23	0.98	130	1.45
P-2608	J-3118	J-2839	600	2539.8	36539.68	1.50	130	3.17
P57117	J14104	J57113	500	1578.4	12000.00	0.71	130	0.98
P-2327	J-171	J-172	600	0.9	86.20	0.00	130	0.00
P-2026	J-379	J-380	600	1.8	86.20	0.00	130	0.00
P-2325	J-115	J-116	600	2.0	86.20	0.00	130	0.00
P-2326	J-159	J-160	600	2.0	86.20	0.00	130	0.00
P51514	J51512	J-3101	600	2.9	86.20	0.00	130	0.00
P-1424_SPL2	J54277	J-3218	600	333.5	649.19	0.03	130	0.00
P-2023	J-3077	J-1992	800	7.9	28462.41	0.66	130	0.49
P-2024	J-1992	J-1993	800	34.7	10174.40	0.23	130	0.07
P-125_SPL2	J21548	J21546	800	46.2	10088.20	0.23	130	0.07
P-1861_SPL1	J-2848	J21559	500	57.2	16626.61	0.98	130	1.79
P-2025_SPL2	J21546	J-762	600	61.0	86.20	0.00	130	0.00
P-2328	J-2305	J-115	600	81.9	86.20	0.00	130	0.00
P-1755_SPL2	J21768	J-3160	500	103.9	17062.62	1.01	130	1.88
P-1423	J-3216	J-2983	600	186.6	5208.52	0.21	130	0.09
P11178	J14104	J14103	600	164.3	48000.01	1.96	130	5.26
P-2027	J-762	J-2597	600	210.3	86.20	0.00	130	0.00
P-2028	J-2597	J-2603	600	220.3	86.20	0.00	130	0.00
P-2664	J-42(2)	J-3196	1400	224.8	202694.30	1.52	130	1.22
P-2480	J-2887	J-42(2)	1400	255.0	196815.75	1.48	130	1.16
P-2606	J-2839	J-3202	600	268.9	36539.68	1.50	130	3.17
P-2329	J-116	J-159	600	277.5	86.20	0.00	130	0.00
P-2025_SPL1	J-1993	J21546	800	286.1	10174.40	0.23	130	0.07
P14117_SPL4	J22313	J22314	300	298.9	746.01	0.12	130	0.07
P14117_SPL2	J22312	J22313	300	350.7	746.01	0.12	130	0.07

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2330	J-160	J-171	600	372.6	86.20	0.00	130	0.00
P14117_SPL6	J22314	J14541	300	421.7	746.01	0.12	130	0.07
P-2191_SPL2	J21545	J-3077	800	564.9	47308.80	1.09	130	1.26
P14117_SPL1	J-3052	J22312	300	462.8	746.01	0.12	130	0.07
P11179	J14103	J14102	600	527.9	48000.01	1.96	130	5.26
P-2549	J-2865	J-2905	1400	493.0	177194.06	1.33	130	0.95
P-2331	J-380	J-2305	600	548.0	86.20	0.00	130	0.00
P-2332	J-172	J51512	600	550.9	86.20	0.00	130	0.00
P-2607	J-3202	J-3216	600	508.4	36539.68	1.50	130	3.17
P-2029	J-2603	J-379	600	567.8	86.20	0.00	130	0.00
P-2456	J-3200	J-2902	1600	595.6	309188.39	1.78	130	1.39
P-1424_SPL1	J-2983	J54277	600	724.5	5208.52	0.21	130	0.09
P18617	J20257	J20479	400	953.4	13013.36	1.20	130	3.38
P-2462	J-2836	J-2927	1600	766.2	310006.00	1.78	130	1.40
P18619	J19771	J19926	300	895.7	0.00	0.00	130	0.00
P-1755_SPL1	J-2810	J21768	500	897.0	14096.22	0.83	130	1.32
P-2463	J-2927	J-3200	1600	1633.3	310006.00	1.78	130	1.40
P18618	J19771	J20257	400	1908.9	13013.36	1.20	130	3.38
P8_SPL2	J5585	J5584	300	2338.0	0.00	0.00	130	0.00
P5588	J11163	J11159	500	2523.7	10840.01	0.64	130	0.81
P-2629	J-3198	J-2865	1400	2632.2	195737.49	1.47	130	1.15
P-2654	J-3196	J-3198	1400	3164.0	200691.08	1.51	130	1.20
P18620	J17532	J19771	400	3584.6	13013.36	1.20	130	3.38
P57119	J57114	J57115	500	251.0	0.00	0.00	130	0.00
P57118	J57113	J57114	400	471.6	0.00	0.00	130	0.00
P57116	J14104	J57112	400	2185.6	12000.00	1.11	130	2.91
P57123	J57118	J57119	500	284.2	7443.20	0.44	130	0.40
P57122	J-4	J57118	500	755.2	7443.20	0.44	130	0.40
P-2543_SPL1	J-3074	J64895	400	156.8	6179.48	0.57	130	0.85
P-1861_SPL2	J21559	J64896	400	225.8	16626.61	1.53	130	5.32
P-2543_SPL2(1)	J64895	J-64915	400	160.5	6179.48	0.57	130	0.85
P-2543_SPL2(2)	J-64915	J-2934	400	948.3	19568.85	1.80	130	7.19
P-1861_SPL4(1)	J64896	J-64914	400	162.8	16626.61	1.53	130	5.32
P-1861_SPL4(2)	J-64914	J-3074	400	60.2	16626.61	1.53	130	5.32
P8_SPL1(1)	J5580	J-64940	600	45.1	3321.60	0.14	130	0.04
P8_SPL1(2)	J-64940	J5585	300	1098.2	3321.60	0.54	130	1.09
P-2436	J-3160	J-2811	500	35.8	17062.62	1.01	130	1.88
P5587_SPL6	J11166	J11167	400	25.9	7680.01	0.71	130	1.27
P-2114	J-3158	J-3155	600	83.6	23405.93	0.96	130	1.39
P5587_SPL8	J11167	J11159	400	164.6	10840.01	1.00	130	2.41
P-1210	J-46(2)	J-2810	600	238.2	13300.53	0.54	130	0.49
P-1640	J-3117	J-46(2)	600	249.3	11109.29	0.45	130	0.35
P-2656	J-2896	J-3136	1200	334.5	142037.22	1.45	130	1.34

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P5587_SPL4	J11165	J11166	400	595.0	7680.01	0.71	130	1.27
P-2595	J-2791	J-2861	1200	151.2	128237.22	1.31	130	1.11
P-1857	J-3110	J-2871	500	659.9	11653.84	0.69	130	0.93
P-2289	J-2859	J-3158	600	665.3	27474.73	1.12	130	1.87
P-884	J-3155	J-3117	600	929.8	15220.36	0.62	130	0.63
P-2596	J-3141	J-2791	1200	1145.6	128237.22	1.31	130	1.11
P-2711	J-2905	J-3134	1200	1225.5	155821.21	1.59	130	1.59
P-2233	J-2811	J-2962	500	1051.2	17062.62	1.01	130	1.88
P-2355	J-2865	J-3110	500	1446.0	18543.44	1.09	130	2.20
P-2657	J-3134	J-2896	1200	1565.8	142037.22	1.45	130	1.34
P-2633	J-3136	J-3141	1200	1593.0	138661.22	1.42	130	1.28
P14114	J-2689	J14147	300	1749.7	2521.44	0.41	130	0.66
P-2206	J-2873	J-2871	300	2127.2	5914.64	0.97	130	3.19
P-2541	J-2902	J-2869	1000	2243.8	113087.79	1.67	130	2.14
P14115	J14147	J-45(2)	300	2860.9	2521.44	0.41	130	0.66
P5587_SPL2	J11164	J11165	400	2536.4	7680.01	0.71	130	1.27
P-2475	J-2869	J-2804	1000	2674.5	106250.93	1.57	130	1.90
P5587_SPL1	J-1	J11164	400	1194.5	0.00	0.00	130	0.00
P-1294_SPL1	J-2893	J57110	400	113.2	12648.00	1.16	130	3.21
P-1293_SPL2	J63085	J-2893	400	2696.6	12648.00	1.16	130	3.21
P-1818	J-865	J-864	600	3.5	86.19	0.00	130	0.00
P-2417	J21548	J-865	600	3.9	86.19	0.00	130	0.00
P51518	J51514	J-3096	600	5.5	86.19	0.00	130	0.00
P-2419	J-1642	J-1643	600	13.5	86.19	0.00	130	0.00
P14116_SPL2	J22309	J22310	300	20.4	746.01	0.12	130	0.07
P22312	J22311	J14379	300	25.6	746.01	0.12	130	0.07
P-2421	J-2352	J-2353	600	97.4	86.19	0.00	130	0.00
P14116_SPL1	J14541	J22309	300	124.1	746.01	0.12	130	0.07
P-2422	J-864	J-2514	600	159.6	86.19	0.00	130	0.00
P14116_SPL6	J22315	J14473	300	219.9	746.01	0.12	130	0.07
P-2423	J-2514	J-2352	600	230.6	86.19	0.00	130	0.00
P-2424	J-2620	J-2621	600	249.7	86.19	0.00	130	0.00
P-2425	J-2353	J-2626	600	254.1	86.19	0.00	130	0.00
P-2426	J-2626	J-1642	600	314.5	86.19	0.00	130	0.00
P-2427	J-1643	J-2620	600	344.2	86.19	0.00	130	0.00
P14116_SPL4	J22310	J22315	300	375.0	746.01	0.12	130	0.07
P-2428	J-2621	J51514	600	436.2	86.19	0.00	130	0.00
P14118_SPL2	J22316	J14473	300	523.1	746.01	0.12	130	0.07
P14118_SPL3	J22317	J22316	300	505.2	746.01	0.12	130	0.07
P-2059_SPL1	J-2808	J14111	300	561.9	649.19	0.11	130	0.05
P14118_SPL1	J14379	J22317	300	657.4	746.01	0.12	130	0.07
P-1919_SPL2	J14542	J-3113	800	879.5	30667.06	0.71	130	0.56
P-1742	J-2872	J-2873	300	2971.6	3698.16	0.61	130	1.33

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P22324	J-46(1)	J-181	250	9.5	6272.44	1.48	130	8.63
P-2807	J-803	J-804	400	9.2	22873.61	2.11	130	9.60
P22325	J-264	J-374	250	15.3	5756.27	1.36	130	7.36
P22322	J-1724	J22321	400	41.8	19007.88	1.75	130	6.82
P57138	J-1634	J63082	250	15.0	4651.79	1.10	130	4.96
FM-BKH1_2	BakkhengWTP1_2	J-2885	2000	309.6	358135.73	1.32	130	0.62
FM-BKH3	BakkhengWTP3	J-2919	1600	44.4	468963.24	2.70	130	3.01
FM-BTM	BTMWTP	J-4	500	20.8	7443.20	0.44	130	0.40
P-3023	J-2912	J-2913	300	8.4	6824.00	1.12	130	4.15
P-2	J-2885	J-2911	600	11.6	0.00	0.00	130	0.00
FM-CCM	ChamcarMonWTP	J-747	800	8.8	123114.35	2.83	130	7.41
P-2350	J-2954	J-2845	1000	1518.0	75244.15	1.11	130	1.00
P-2539	J-3096	J-3101	300	2461.5	86.20	0.01	130	0.00
P14108	J14106	J14107	300	135.5	911.33	0.15	130	0.10
P14109_SPL2	J14113	J14108	300	154.0	911.33	0.15	130	0.10
P-2112	J-2933	J-2849	300	158.5	10442.53	1.71	130	9.13
P14112	J14110	J14111	300	291.3	911.33	0.15	130	0.10
P14109_SPL1	J14107	J14113	300	305.4	911.33	0.15	130	0.10
P14107	J14105	J14106	300	548.3	911.33	0.15	130	0.10
P14106	J-2849	J14105	300	544.8	911.33	0.15	130	0.10
P14110	J14108	J14109	300	535.5	911.33	0.15	130	0.10
P14111	J14109	J14110	300	1099.1	911.33	0.15	130	0.10
P-2371	J-45(2)	J-46(2)	300	1496.8	2521.44	0.41	130	0.66
P-2059_SPL2	J14111	J-2809	300	486.2	500.36	0.08	130	0.03
P-1835	J-3212	J54277	500	23.3	5857.71	0.35	130	0.26
P-1087_SPL2	J22311	J-3018	400	256.5	4872.27	0.45	130	0.55
P-1094	J-3018	J-3008	400	261.6	4872.27	0.45	130	0.55
P-1087_SPL3	J57126	J22311	400	1406.0	5618.29	0.52	130	0.71
P-14(1)(1)	J-3218	J64903	500	985.6	0.00	0.00	130	0.00
P-2778_SPL2	J41932	J-2891	500	162.3	40832.01	2.41	130	9.47
P-1087_SPL1	J-2962	J57126	500	947.0	5618.29	0.33	130	0.24
P41936	J20481	J-2831	600	161.3	48232.08	1.97	130	5.31
P-2594_SPL2	J20480	J-2794	800	357.7	42423.32	0.98	130	1.03
P41935	J-2785	J-2786	600	384.2	32636.04	1.34	130	2.57
P-2288	J-3173	J-2859	600	20.1	25811.06	1.06	130	1.67
P-2454	J11171	J-3173	600	1153.0	30667.06	1.26	130	2.29
P63089	J11171	J-3113	600	17.2	30667.06	1.26	130	2.29
FM-CCW	CCWWTP	J-2907	1200	9.7	180911.35	1.85	130	2.10
FM-PPK	PhumPrekWTP	J-1026	1250	10.4	361106.19	3.41	110	8.43
FM-TKM	TaKhmaoWTP	J-2912	600	7.9	54132.80	2.22	130	6.57
FM-TMK	TaMoukWTP	J-2921	1600	7.0	308928.49	1.78	130	1.39
FM-NRD3	NirodhWTP3	J-2952	2000	15.6	411604.14	1.52	130	0.80
P-2579	J-2952	J-3076	2000	63.7	411604.14	1.52	130	0.80

Label	Node1	Node2	Diameter (mm)	Length (m)	Q (m^3/day)	V (m/s)	C	I (‰)
P-2580_SPL2	J57097	J64900	2000	131.0	411604.14	1.52	130	0.80
P-2580_SPL1	J-3076	J57097	2000	192.6	411604.14	1.52	130	0.80
P57111_SPL2	J64901	J64902	2400	430.0	290508.91	0.74	130	0.17
P63090(1)	J57107	J-39	2200	60.0	191025.45	0.58	130	0.12
FM-KND	KhsachKandalWTP	J-3057	1200	223.5	156267.20	1.60	130	1.60
FM-NAP	NewARPTWTP	J54278	700	39.2	38244.00	1.15	130	1.63
FM-NRD1_2	NirodhWTP1_2	J-1005	1600	8.9	414116.41	2.38	130	2.39

ANNEX 10 PIPE DETERIORATION FORECAST USING AI

Entrustment on the Water Supply Pipeline Deterioration Diagnosis for Contributing to the DX Introduction Survey in the Feasibility Study of Nirodh Water Supply Expansion Project

Final Report

November 2023

Tenchijin, Inc.,

Contents

1. Introduction

In recent years, with the economic growth, rapid population increase, and urban expansion of Phnom Penh, the capital city of the Kingdom of Cambodia, the demand for water resources has been increasing. Effective management and maintenance of the water supply system have become crucial. Leakage, in particular, has emerged as a major challenge hindering the efficient operation of the water infrastructure, calling for effective risk management in response.

In this project, Tenchijin, Inc., (hereinafter "Tenchijin") has been commissioned by Kitakyushu Water Service Co., Ltd. (hereinafter "KWS") to undertake the work. The project aims to digital transformation (hereinafter DX) the water management system in Phnom Penh and utilize the data held by the Phnom Penh Water Supply Authority (hereinafter "PPWSA"). It includes an assessment of the leakage risk due to pipeline aging, as well as an investigation into the feasibility of demonstrating the assessment of this risk.

It should be noted that the terrestrial data used in the leakage risk assessment currently conducted by Tenchijin for domestic municipalities differs in terms of data type and temporal/spatial resolution from the terrestrial data held by PPWSA. However, the risk assessment methods used are equivalent to those used in Japan, and the satellite data used are also common. This report presents the findings of these output.

2. Outline of the work

2.1. Outline

In this work, we conducted a demonstration of leakage risk assessment in the administrative areas of Phnom Penh. The data used included water pipeline and leakage repair data, environmental data, and satellite data. These collected data were processed and formatted to be suitable for analysis. Regarding the relationship between leakage and various data, we analyzed the trends of leakage in relation to the year of installation, type of pipe, land use, and other factors that may influence leakage trends.

Based on the insights gained from the analysis, we applied supervised machine learning, which can represent leakage patterns in high-dimensional data, to construct a highly accurate risk assessment model.

The analysis of the leakage risk assessment model revealed that the main factors influencing leakage risk are the length of the pipeline, year of installation, diameter, land use, population density, and surface temperature. This analysis of the leakage risk assessment model enabled us to demonstrate the leakage risk assessment in Phnom Penh. The leakage risk was evaluated on a 5-point scale, identifying areas with high and low risk. Overall, it was confirmed that there is sufficient data available to conduct leakage risk assessments in Phnom Penh.

2.2. Target

The main objective of this project is to demonstrate the assessment of inferred leakage risks within the water supply area of Phnom Penh city by combining data obtained from human satellite images, open data, and KWS's water pipeline and leakage repair data. Through our proprietary AI analysis, we aim to effectively and efficiently promote the updating project and the prevention of water leakage in the water supply system, as well as its maintenance management. The goal is to report on the results, lessons learned, and challenges encountered in this endeavor.

2.3. Subject of entrustment

Entrustment on the Water Supply Pipeline Deterioration Diagnosis for Contributing to the DX Introduction Survey in the Feasibility Study of Nirodh Water Supply Expansion Project

2.4. Contract period

From 8th September 2023 to 31st December 2023

3. Pre-survey related to the leakage risk management

3.1. The status and Master Plan of the water supply in Phnom Penh

Phnom Penh city has set a goal, in line with the National Strategic Development Plan, to ensure 100% access to safe water for urban residents by 2025. Since 1993, in collaboration with donor countries such as Japan, efforts have been made to construct and refurbish water treatment plants, expand the distribution network of water pipes, and provide technical support. These initiatives have led to the realization of 24-hour water supply and an increase in the water supply rate to over 90%.

However, with rapid economic growth, urban expansion, and the increase in commercial facilities, the average daily water demand reached 642,000 cubic meters per day in 2022, exceeding the supply capacity of 592,000 cubic meters per day. Particularly, in some areas, the construction of buildings and large commercial facilities has led to low water pressure and deterioration in water quality.

In response to this, PPWSA has forecasted that by 2030, the population will approach 3 million people, and the average daily water demand will increase to 1,578,000 cubic meters per day. In 2022, the Third Master Plan was updated to address this forecast. This plan, developed with the assistance of France in 2015, includes plans for water supply from the eastern side of the Mekong River, Sap River, and Bassac River as the western part of the city lacks stable water sources and water treatment plants.

The Master Plan includes the construction of the Chamcar Mon Water Treatment Plant (52,000 cubic meters/day), the Bakheng Water Treatment Plant (Phase 1: 195,000 cubic meters/day, Phase 2: 195,000 cubic meters/day), the Ta Khmao Water Treatment Plant (30,000 cubic meters/day), and the Phum Prek Water Treatment Plant (improvement and expansion to 195,000 cubic meters/day). The plan aims to increase the total facility capacity to 1,057,000 cubic meters per day by 2030.

PPWSA has incorporated measures in the Master Plan to address the low water pressure and improve water quality resulting from the construction of buildings and large commercial facilities. These efforts contribute to the sustainable development of Phnom Penh and the enhancement of the city's quality of life, aligning with international cooperation and planning based on regional needs to strengthen the urban water supply infrastructure.

3.2. Feasibility study

In the execution of the Japan International Cooperation Agency's (herein after JICA) project implementation contract "Cambodia Niroth Water Supply Expansion Project Feasibility Study," the purpose is to conduct the necessary investigations for the scrutiny of the project as a yen loan project of Japan, including the objectives, overview, cost estimation, implementation schedule, implementation (procurement and construction) method, operation and maintenance system, and considerations for environmental and social aspects, based on the request from PPWSA.

In this context, the aim is to utilize data from PPWSA to contribute to the efficient maintenance management of water facilities within Phnom Penh city, and to demonstrate digital technologies that can be introduced by PPWSA.

3.3. Supposed user

In demonstrating the leakage risk assessment for this task, the user is assumed to be PPWSA. PPWSA inputs water pipeline and leakage repair data into the leakage risk assessment, combines it with environmental data held by Tenchijin, and satellite data, and outputs the assumed output for PPWSA as the user.

Specifically, the Water Loss Reduction Office and the Commercial Department of PPWSA are assumed to be the users. Through the leakage risk assessment, the former is responsible for comprehensively understanding the leakage risk situation and determining the priority of inspection points, while the latter is assumed to carry out on-site inspections and reporting according to the determinations.

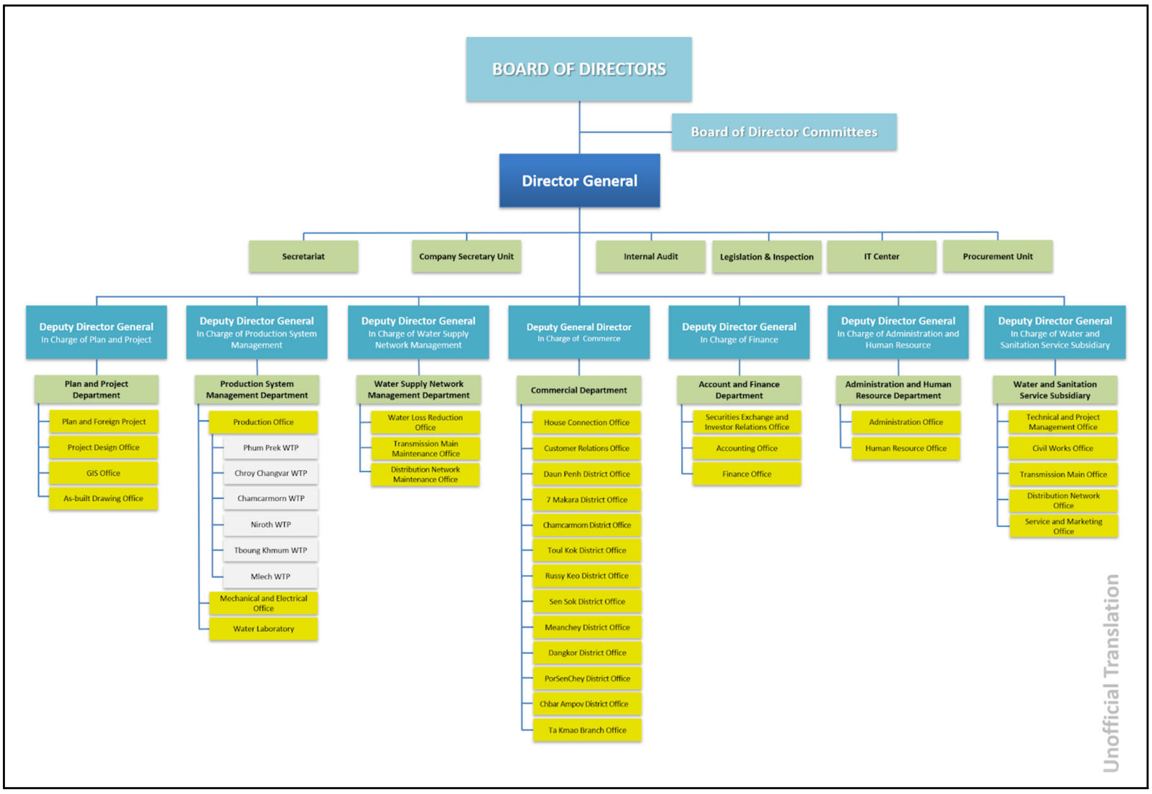


Figure3-1 Organization Chart in PPWSA

4. Demonstration of the leakage risk evaluation

In this work, the verification of the validity of the leakage risk assessment and verification results in the field is not within the scope. Therefore, we have adopted an approach to enhance the reliability of the analysis results by using data that is considered to be of high importance and is close to the data used in the model that has been validated domestically. As shown in Table 4-4, the data of high importance corresponds to the data used in all municipalities A, B, and C in Japan. On the other hand, among the types of data used domestically, there are some that could not be used in this task due to unavailability. To further improve the analysis results, it is necessary to collect repair history data such as "replacement date" and "shape update date" of the pipelines, and a system to input and manage the increasing data due to future DX is also deemed necessary.

In the verification of the leakage risk assessment for this work, we used water pipeline and leakage repair data, environmental data, and satellite data. We analyzed the relationship between leakage and various data, examining the potential influences of installation year, pipe type, land use, and leakage trends. Based on the insights gained from the analysis, we applied supervised machine learning capable of representing leakage patterns in high-dimensional data to construct a high-accuracy risk assessment model. The analysis results of the leakage risk assessment model suggested that the major factors affecting leakage risk are the length of the pipeline, installation year, diameter, land use, population density, and surface temperature. We evaluated the leakage risk on a five-point scale and identified areas of high and low risk.

4.1. The target and implementation plan of leakage risk assessment

This section describes the objectives and implementation plan of the leakage risk assessment. The main objectives of the leakage risk assessment are as follows:

1) To demonstrate the leakage risk assessment and identify sections of water pipelines with a high risk of leakage occurrence. This aims to explore the feasibility of early detection and efficiency improvement of leakage.
2) To organize the maintenance status of the water pipeline leakage repair data in Phnom Penh, as well as the availability of environmental data and satellite data, through the process of conducting the leakage risk assessment.
3) To investigate the feasibility of introducing GIS leakage risk management services.

The implementation plan for the leakage risk assessment is as follows:

1) The analysis scope includes the entire water pipeline network within the administrative regions of Phnom Penh.
2) The methodology for calculating leakage risk adopts a comprehensive evaluation method that combines water pipeline data, leakage repair records, environmental data, and satellite data.

4.2. The potential of data utilization on targeted area

This section discusses the potential for data utilization in the administrative regions of Phnom Penh for the leakage risk assessment. The available data has been classified and organized into the following three categories: water pipeline and leakage repair data, environmental data, and satellite data.

4.2.1 Provided data

The table below (Table 4-1) outlines the data provided by KWS to Metawater for the leakage risk assessment. All of the data, except for Customer (water utility customer information), was utilized for the analysis conducted as part of the leakage risk assessment.

Table 4-1 The list of the provided data from KWS to Tenchijin

Data	Type	Use / Not Use	File Type
Customer	Customer information	Not Use	Point data
Leakage	Leakage information	Use	Point data
Pipeline	Water supply pipeline	Use	Line data
Rail Road	Rail road	Use	Line data
Road	Road	Use	Line data
Geo boundaries	Border	Use	Polygon data

Definition of the analysis area

The Geo Boundaries data was utilized to define the geographical boundaries, and the Area of Interest (AOI) for the analysis was defined from the boundaries of ADM1 (Figure 4-1). It is noted that the water pipelines located to the northeast of Phnom Penh city were excluded from the analysis scope.

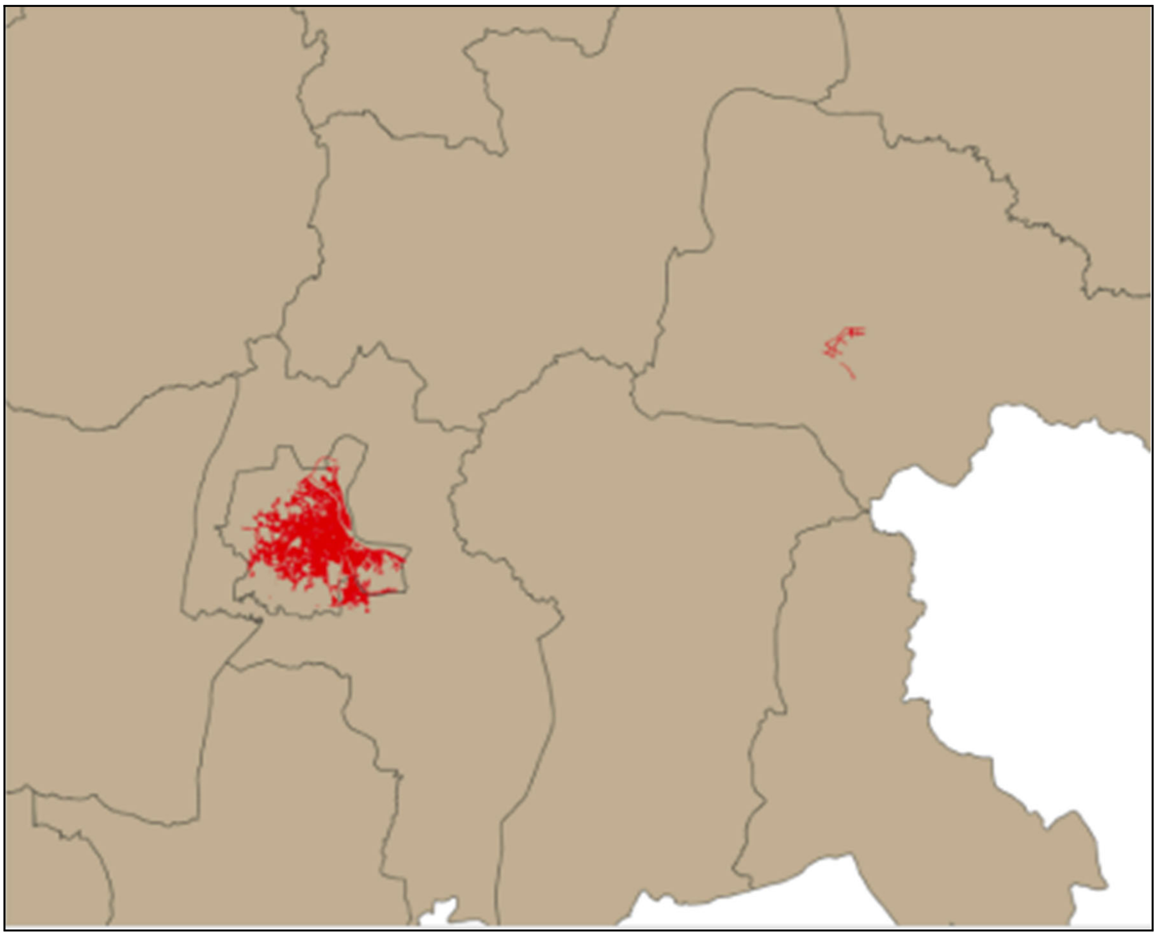


Figure 4-1 Analysis Area (Administrative area of Phnom Penh, and the pipeline)

Coordinate System Transformation

The coordinate system of the data provided by KWS to Tenchijin was in the UTM coordinate system (EPSG:32648). However, for the analysis, the coordinate system was transformed to the

World Geodetic System (EPSG:4326).

4.2.2 Water supply pipeline and leakage repair data

The water pipeline data and leakage repair data are foundational datasets for understanding the current infrastructure and evaluating leakage risks in Phnom Penh. This includes basic information such as the location, material, diameter, installation year of the pipelines, as well as historical records of past leak occurrences and repair operations.

Water Suply Pipeline Data

The types of water pipelines used in Phnom Penh were categorized using the Function attribute of the water pipeline data (Table 4-2). The geometry of the water pipeline data included a Multilinestring type, which was decomposed into individual Linestring types for analysis due to processing constraints.

The primary attributes of the water pipeline data are summarized in Table 4-3. Additionally, when comparing the water pipeline data of Phnom Penh with several municipalities in Japan, there are common attributes as well as attributes specific to Phnom Penh (Table 4-4). Unique identifiers for identifying pipelines, installation years, diameters, pipe materials, and distribution zones were common attributes between Phnom Penh and Japan. On the other hand, attributes indicating road names or the condition of water pipelines were specific to Phnom Penh's management. The burial classification (depth) was managed in Phnom Penh and similarly in some municipalities in Japan.

Table4-2 The Type of the Water Supply Pipe in Phnom Penh

Attribution	Description	Number	Total Length [km]
Transmission (TM)	Transmission	3,172	3,388.0
Distribution	Distribution	45,575	357.5
Service pipe	Service pipe	259	11.6
Raw Water	Conduit pipe	1	2.6
No flag	No description	126	93.3
Total		49,133	3,853.0

Table 4-3 Main Attribution Name on Water Supply Pipe Data

Attribution Name	Description	Using Method
fid_1	ID	It is decomposed from Multilinestring type to Linestring type, and put ID individualy
STREET	Street number	Use after transform to the code
LENGTH_R	Install length	Use after recalculation from geometry
DIAMETER	Diameter	Use
MATERIAL	Pipe material	Use. Attributions includes DI, HDPE, PIPE, PVC, empty.
FUNCTION	Function of the Pipe	Use
STATE	Status	Use. Attribution includes In use, Missing, Moved, Relocated, empty.
DATE_IN	Install date	Use.
YEAR_IN	Install yeat	Use. However, some data is not match with DATE_IN.
DEPTH	Install depth	Use.
LENGTH_C	Length (Detail)	Use after recalculate by geometry.
DISTRICT	District Number	Use. However, detail is not clear.

Table 4-4 Comparison of the data attribution on Japanese local Government

Water Supply Pipeline attribute	Phnom Penh	Japanese local Government A	Japanese local Government B	Japanese local Government C
ID	○	○	○	○
Inauguration Fiscal Year	DATE(YEAR)_IN	○	○	○
Diameter	DIAMETER	○	○	○
Pipe Type (Material)	MATERIAL	○	○	○
Class		○		
Install Depth (Depth)	DEPTH	○		
District Metered Area	DISTRICT	○	○	○
Replacement Date		○		○
Type Update Date			○	○
Consumption Amount			○	○
Main or Branch			○	
Joint Quantity			○	○
Inside Coating			○	
Essential Facility			○	
Attached Feature Quantity				○
Surface Length				○
Pipe Beam Flag				○
Street	STREET			
Status	STATE			

Leakage Data

The leakage data were categorized based on the types of pipes where leaks occurred, and the number of leaks was recorded for each category (Table 4-5). The LEAKAGES and LEAKS_F columns recorded leaks that occurred in supply or distribution pipes. The data did not include attributes to differentiate pipe types, making it difficult to distinguish between them. LEAKS_C recorded leaks specifically in supply pipes.

Additionally, the attributes of the leakage data included information relevant to future leakage prevention efforts in Phnom Penh, such as the type of leakage, its causes, and traffic volume (Tables 4-6 to 4-8).

Table 4-5 Outline of the Leakage Data

Data Name	Pipe Type Targeted on Survey	Leakage Number
LEAKAGES	Transmission or Distribution	944
LEAKS_F	Transmission or Distribution	477
LEAKS_C	Service Pipe	9,298

Table 4-6 Case of the Leakage

Attribution Item	Description
Crack	- Crack
Dislocation	- Pipe Movement
Gasket problem	- Gasket Issue
Hole	- Tree Root
Joint Leak	- Leakage at Joints
Leak on Joint Section	- Leakage at Joints
Longitudinal break	- Vertical Damage
Neat break	- Clean Break
Other	- Other
Other / Unknown	- Other/Unknown
Pipe Burst	- Pipe Burst
Pipe Cracking	- Pipe Crack
nan	- Blank

Table 4-7 Cause of Leakage

Attribution Value	Description
Affected by Outside Force	- External Force Impact
Age (old)	- Deterioration
Bad material	- Material Defect
Chopped from Anonymous	- Deliberate Cut
Ferrous	- Oxidation
Fusion Malpractice	- Poor Joint
Ground Settlement	- Ground Subsidence
Ground movement	- Ground Movement
Internal corrosion	- Internal Corrosion
Intruded by Tree Roots	- Contact with Tree Roots
Low Quality Product	- Product Defect
Other	- Other
Other / Unknown	- Other/Unknown
Other Sites not Related to PPWSA	- Area Outside PPWSA's Management
Over Age of Pipe	- Ageing Deterioration
Third party damage	- Damage by Third Party
Unknown	- Unknown
nan	- Blank

Table 4-8 Traffic Dencity

属性値	説明
Heavy traffic: Truck, Bus, many cars	High Density: Truck, Bus, Many Cars
Light traffic (bicycles, motorbikes, tuck-tuck)	Low Density: Bicycle, Motor Bike, TukTuk
No traffic (natural zone or pathways)	No Density: No Traffic, Natural or Sidewalk
Traffic with many cars, pick-up (no truck/bus)	Many Cars, Pick & Drop: Many Car and Pickup-Dropoff. But No Truck and Bus
nan	Blank

4.2.3 Environmental Data

Environmental data includes information about the physical or socio-economic environment, such as terrain, soil, land use, and population density. These data are essential for evaluating the spatial distribution and trends of leakage risks, taking into account the natural environment and social background of the area.

Table 4-9 The List of Utilized Environmental Data

Data Category	Data Name
Terrain Data	Global Terrain Classification using 280m DEMs
Terrain Class 2	Terrain22 (Global GeoTIFF)
Soil Type 1	Distribution of soil types in Cambodia(Crocker, 1962)
Soil Type 2	Digital Soil Map of the World
Surface Geology	Geology of Cambodia (2006)
Land Use	Land cover in Cambodia (2015-2020)
Urban Land Use	Phnom Penh (Cambodia)-Land Use/Land Cover Maps (ESA EO4SD-Urban)
Population Density Data	Population density
Household-related Data	Population census 2019
Topographical Data	ASTER global digital elevation model (ASTER GDEM) in Cambodia

Terrain Data

The terrain data was obtained from the Global Terrain Classification using 280m DEMs. This dataset is based on a 280m Digital Elevation Model (DEM) and includes a terrain classification map segmented into 15 types of terrain. The Lambert azimuthal equal-area projection method was used, and the data covers the entire globe.

Data Name	Global Terrain Classification using 280m DEMs
Data Type	Shapefile
Information of Attribute Table	Group: 15 Groups Class: 40 Classes
Referred Document	Iwahashi, J., Kamiya, I., Matsuoka, M. and Yamazaki, D. (2018) Global terrain classification using 280 m DEMs: segmentation, clustering, and reclassification. Progress in Earth and Planetary Science, 5:1.
For Commercial Use	ASK

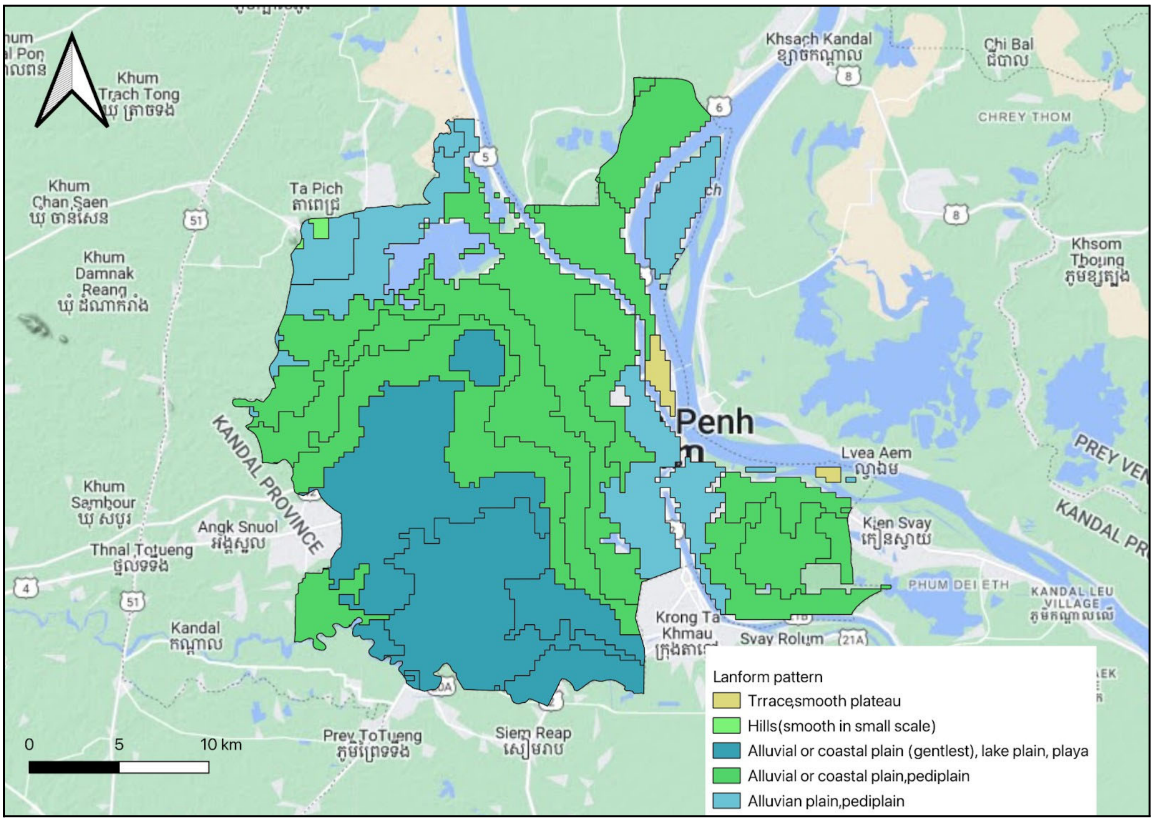


Figure 4-2 Phnom Penh Terrain Category Map 1

Terrain Classification 2

Terrain Classification 2 was created based on the Global Polygon Data developed by Iwahashi et al. This data consists of a global polygon dataset for terrain classification, segmented into uniform slopes and basins, specifically distinguishing between slopes and basins. The coverage area is Southeast Asia.

Data Name	Terrain22 (Global GeoTIFF)
Data Type	geotiff
Referred Document	Iwahashi, J. and Yamazaki, D. (2022) Global polygons for terrain classification divided into uniform slopes and basins. Prog Earth Planet Sci 9, 33.
For Commercial Use	CC-BY-NC 4.0

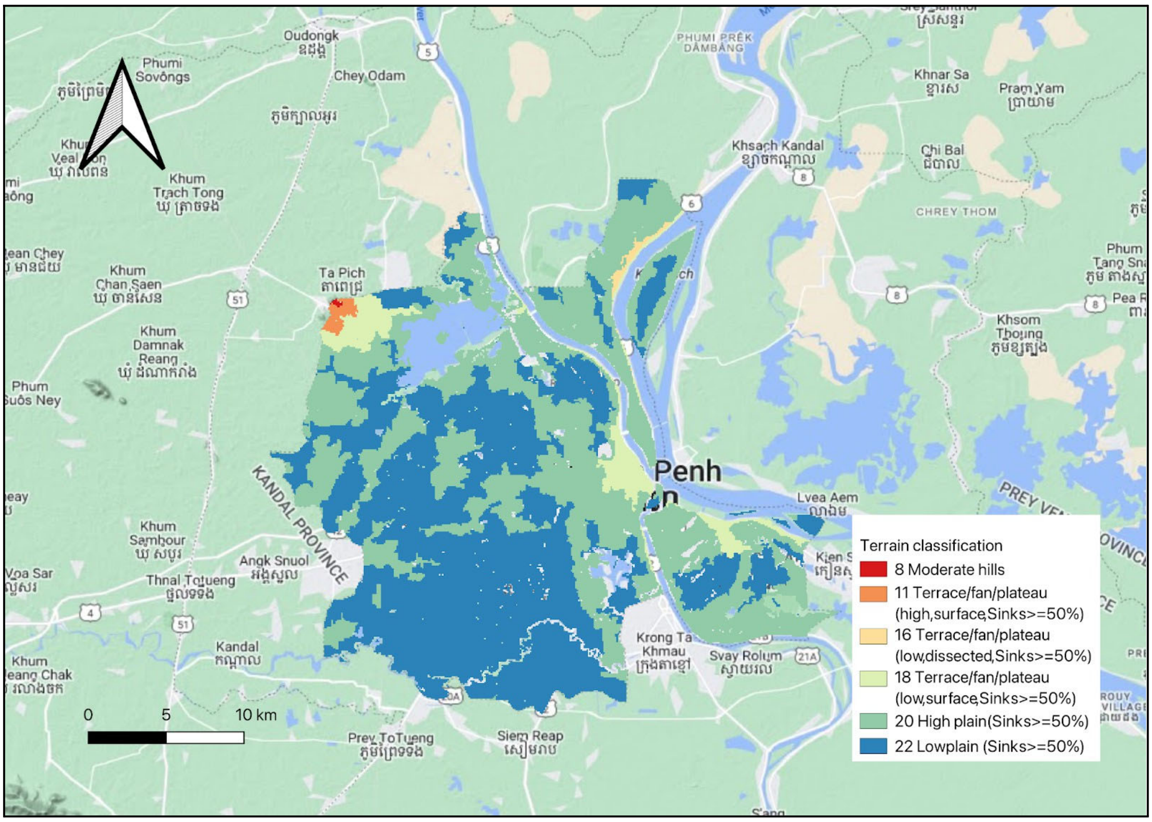


Figure 4-3 Phnom Penh Terrain Category Map 2

Soil Classification 1

Soil Classification 1 categorizes the soils of Cambodia into 16 types. Developed by Crocker (1962) and provided by Save Cambodia's Wildlife (SCW), this classification system categorizes soil types into 16 categories.

Data Name	Distribution of soil types in Cambodia (Crocker, 1962)
Data Type	Shapefile
Information of Attribute Table	Soil Category: 16 Category
Referred Document	Crocker, C.D. 1962. The General Soil Map of the Kingdom of Cambodia and the Exploratory Survey of the Soils of Cambodia. Royal Cambodian Government Soil Commission/USAID Joint Publication, Phnom Penh.
For Commercial Use	CC-BY-SA-4.0

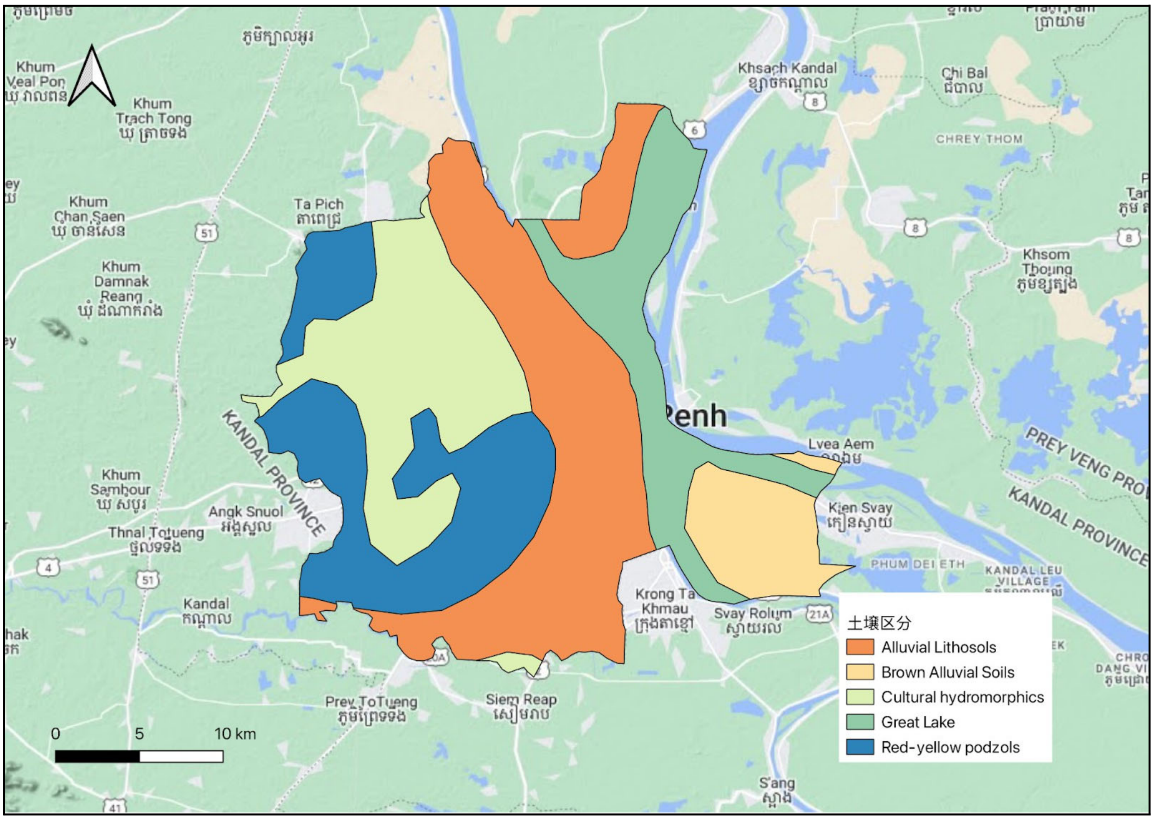


Figure 4-4 Phnom Penh Soil Classification 1

Soil Classification 2

Soil Classification 2 is a digital map classifying soils worldwide, provided by the Food and Agriculture Organization (FAO). The data is based on the FAO-UNESCO dataset.

Data Name	Digital Soil Map of the World
Data Type	Shapefile
Information of Attribute Table	FAOSOIL: Soil Category (detail) DOMSOI: Soil Category COUNTRY: Country
For Commercial Use	ASK

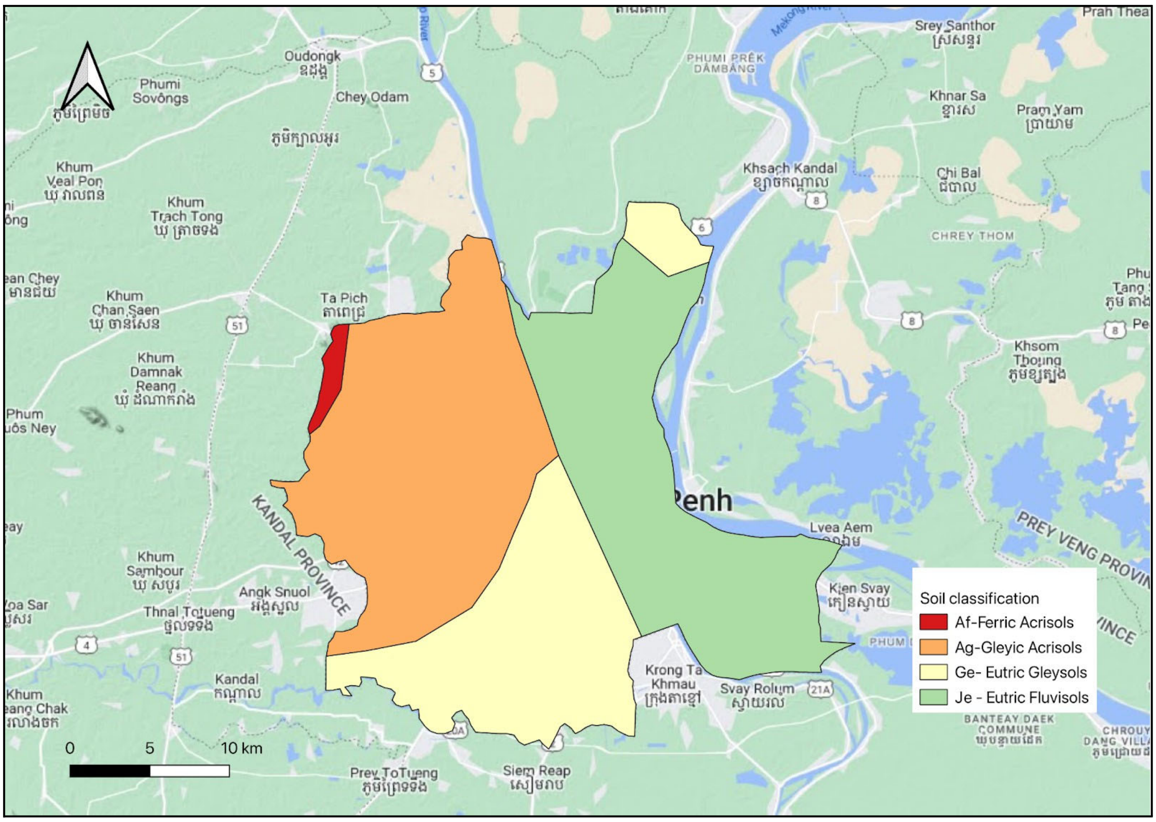


Figure 4-5 Phnom Penh Soil Classification 2

Surface Geology

Surface geology data, including information on the surface geology of all soils in Cambodia, was provided by Save Cambodia's Wildlife's Atlas Working Group.

Data Name	Geology of Cambodia (2006)
Data Type	Shapefile
Information of Attribute Table	Name: Geology Category
For Commercial Use	CC-BY-SA-4.0

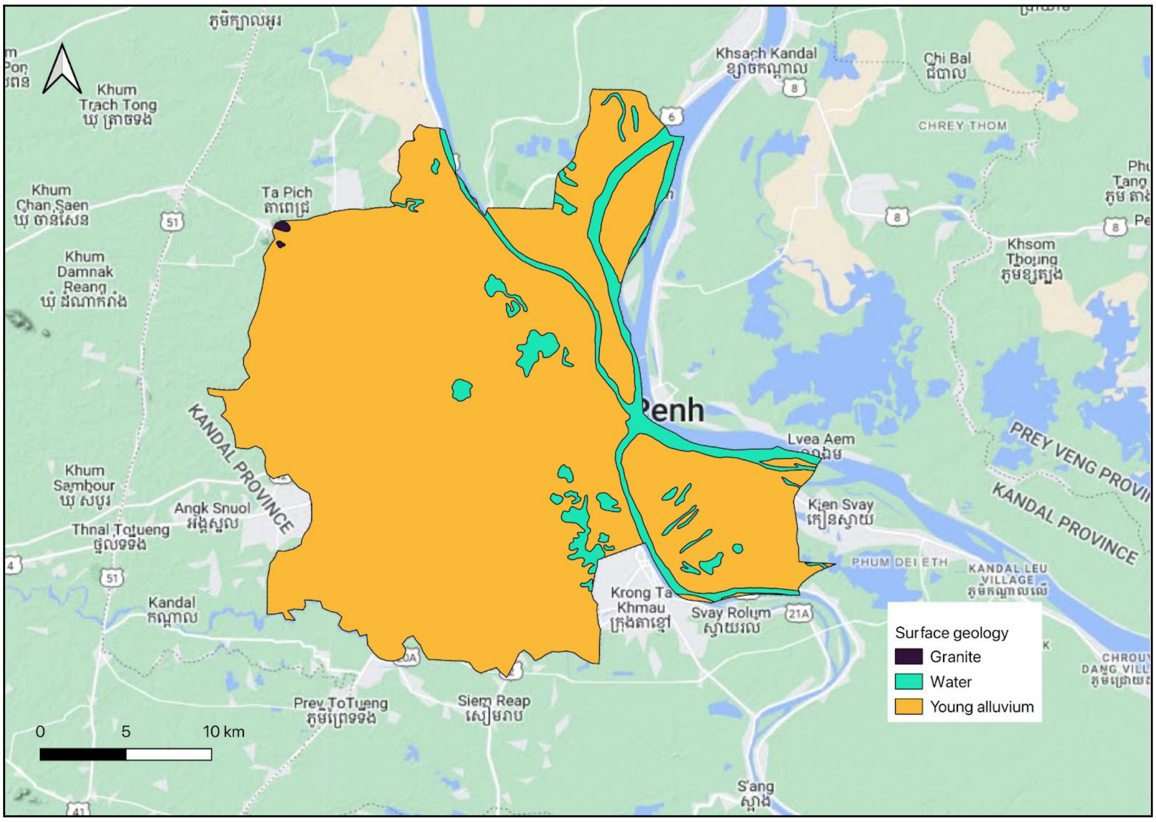


Figure 4-6 Phnom Penh Surface Geology Map

Land Use

Land use data was provided by Open Development Cambodia, showing the land cover changes in Cambodia from 2015 to 2020.

Data Name	Land cover in Cambodia (2015-2020)
Data Type	geotiff
For Commercial Use	CC-BY-SA-4.0

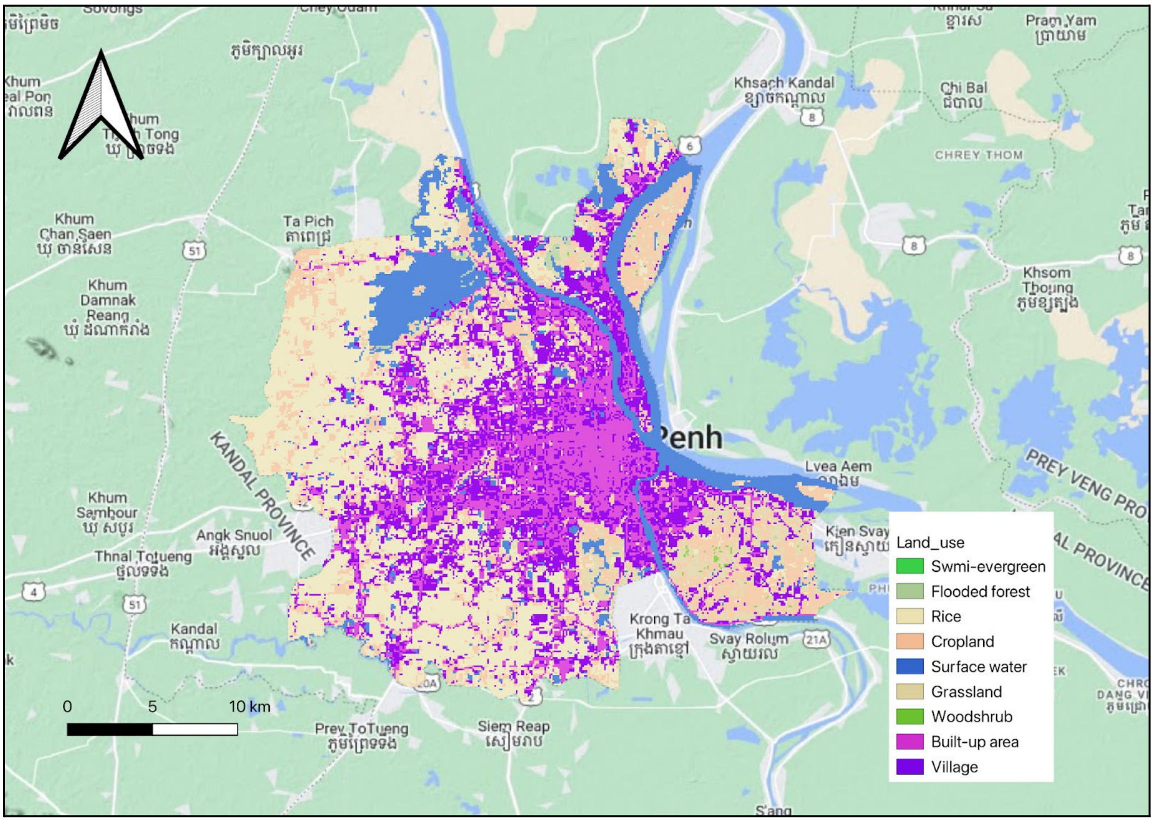


Figure 4-7 Phnom Penh Land Use Map

Urban Land Use

Urban land use data, provided by The World Bank, includes information on the main areas of land use in Phnom Penh. The dataset includes data from two points in time, 2003 and 2017, enabling observation of changes in urban land use over time. The data was created using both high-resolution (Level 3-4) and low-resolution (Level 1-2) satellite images, allowing for analyses based on varying levels of detail.

Data Name	Phnom Penh (Cambodia)-Land Use/Land Cover Maps (ESA EO4SD-Urban)
Data Type	Shapefile
Information of Attribute Table	C_L4 ¨ level 4 N_L4 ¨ level 4 C_L3 ¨ level 3 N_L3 ¨ level 3 C_L2 ¨ level 2 N_L2 ¨ level 2 C_L1 ¨ level 1 N_L1 ¨ level 1
For Commercial Use	CC-BY-SA-4.0

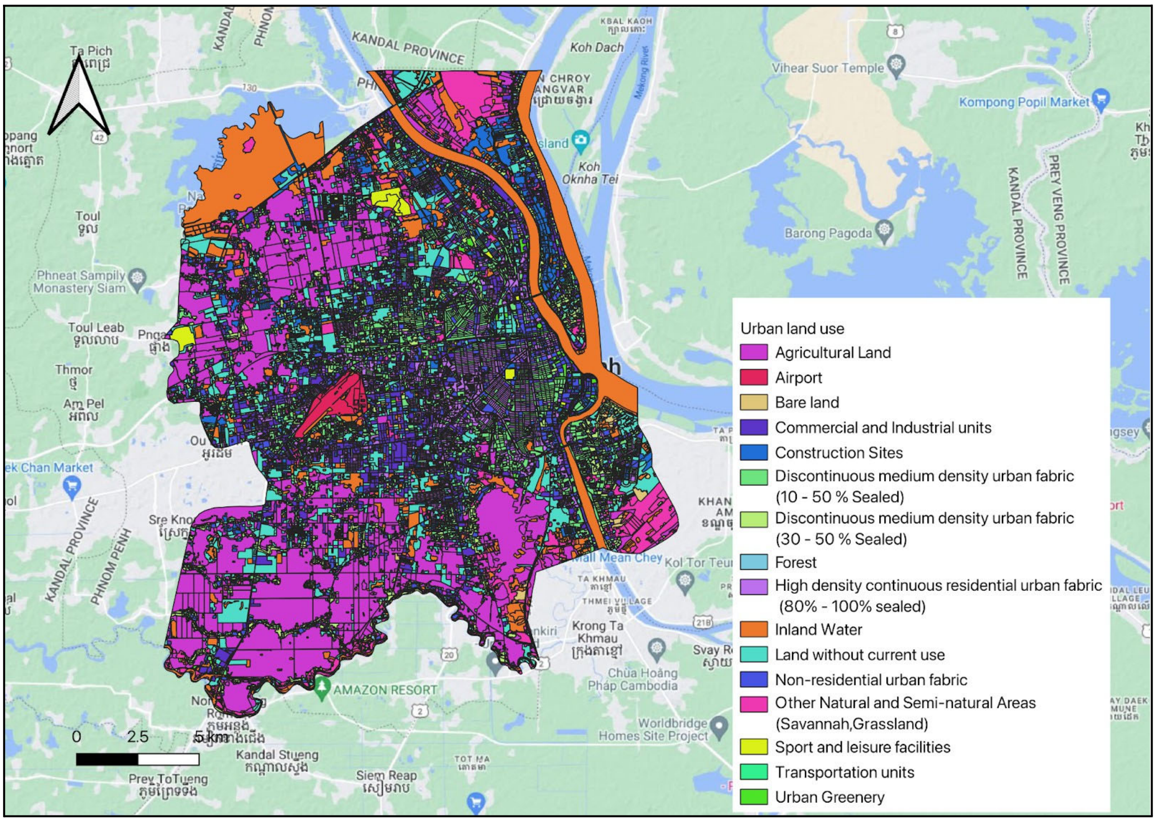


Figure 4-8 Phnom Penh Urban Land Use Map

Population Density Data

Population density data, covering all of Cambodia, was provided by Open Development Cambodia. This data is based on the 2008 Cambodia Population Census.

Data Name	Population density
Data Type	geojson
For Commercial Use	CC-BY-SA-4.0

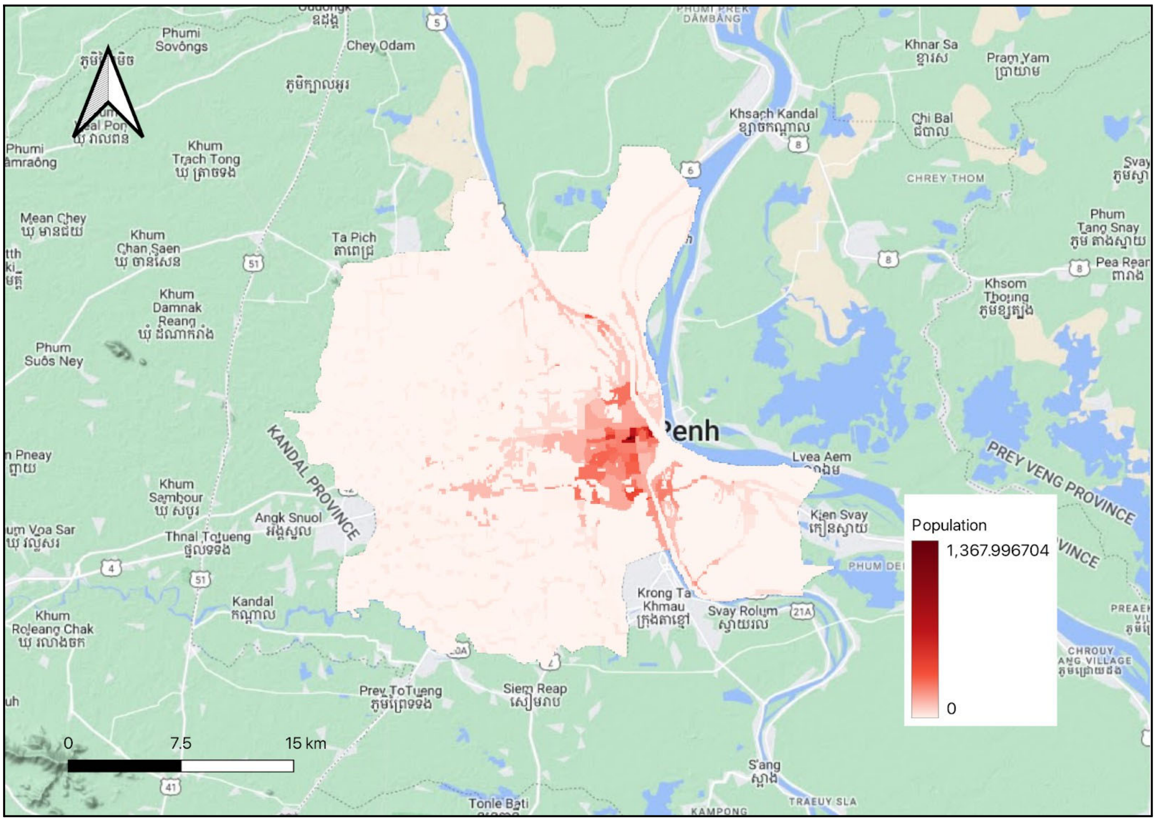


Figure 4-9 Phnom Penh Population Density Map

Household-related Data

Household-related data provides information on the total population (male, female), total households, household size, density, and area by province in Cambodia, as provided by the National Institute of Statistics of the Ministry of Planning. This data is based on the 2019 Cambodia Population Census.

Data Name	Population census 2019
Data Type	geojson
For Commercial Use	CC-BY-SA-4.0

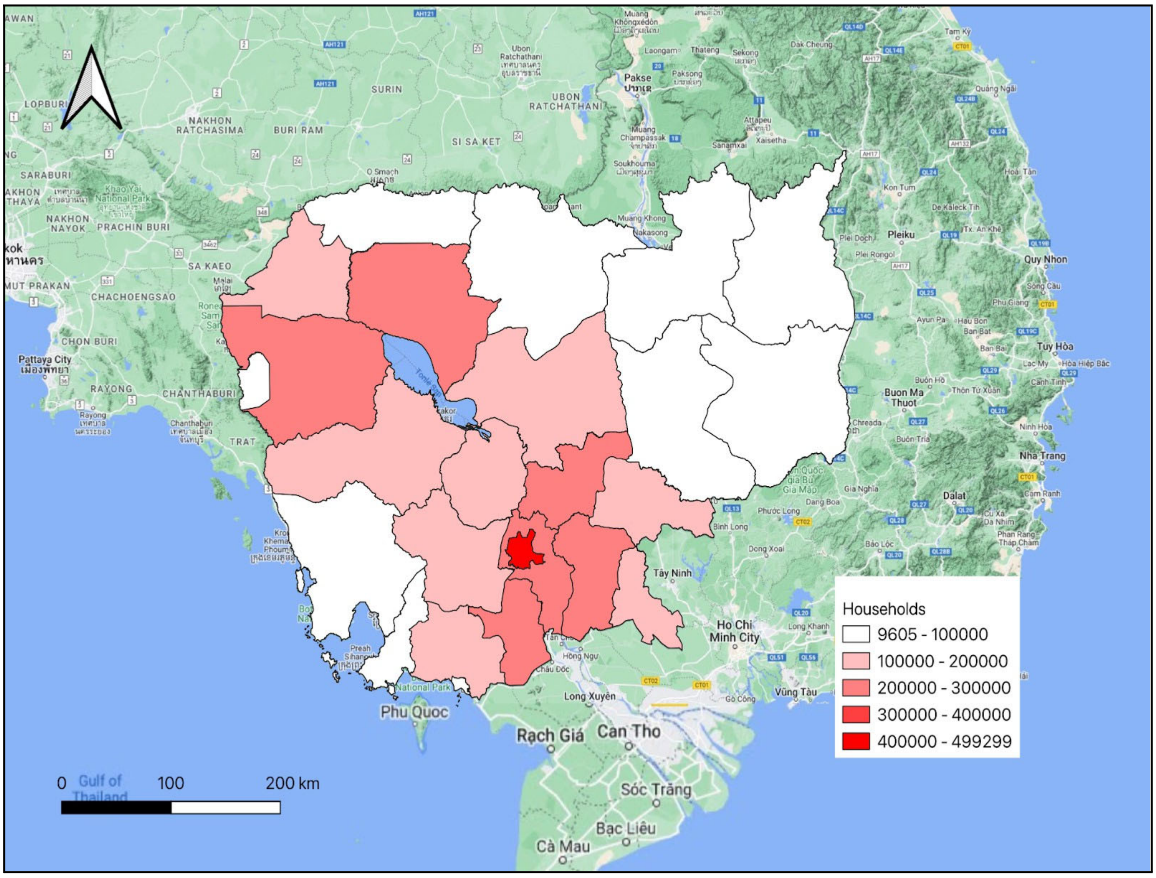


Figure 4-10 Cambodia Household Quantity Map

Elevation Data

Elevation data for the entirety of Cambodia is provided by a collaboration between Japan's Ministry of Economy, Trade and Industry (METI) and the National Aeronautics and Space Administration (NASA). This data, created using the sensor "ASTER" aboard artificial satellites, provides numerical elevation data.

Data Name	ASTER global digital elevation model (ASTER GDEM) in Cambodia
Data Type	geotiff
For Commercial Use	CC-BY-SA-4.0

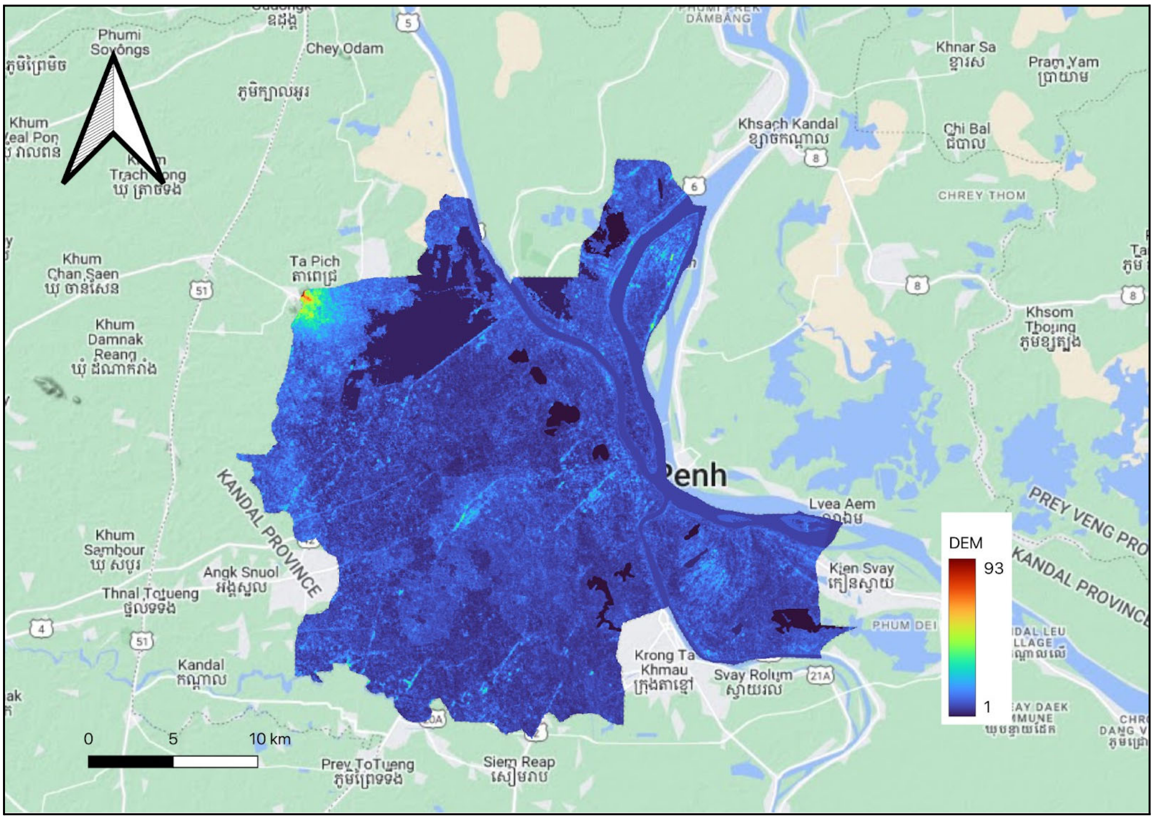


Figure 4-11 Phnom Penh DEM Elevation Map

Gradient Data

Gradient data was calculated using GIS gradient calculation functions based on the aforementioned Elevation Data.

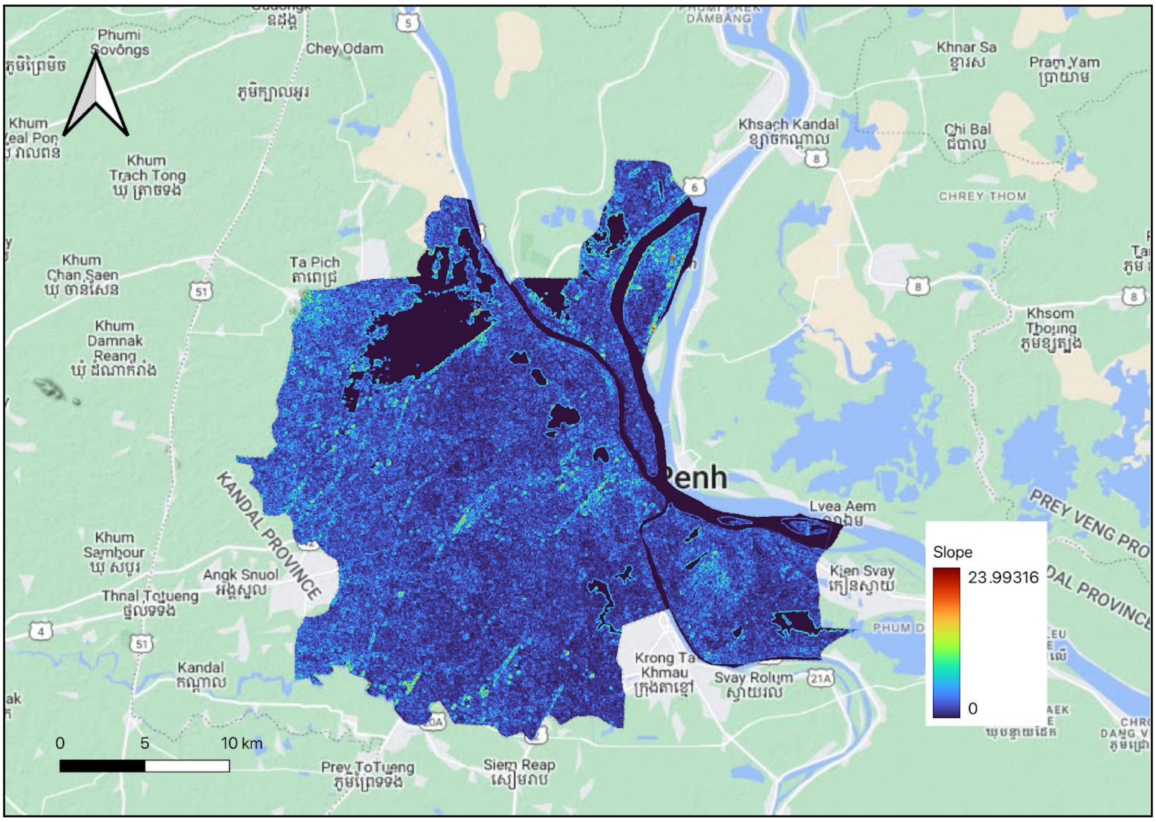


Figure 4-12 Phnom Penh Gradient Map (Gradient Angle)

4.2.4 Satellite Data

Satellite data refers to observations of the Earth's surface conditions, such as land surface temperature, captured by artificial satellites. One of its distinguishing features is comprehensive access to historical data, irrespective of stakeholder interests.

Furthermore, land cover based on satellite data has been categorized as environmental data.

<u>Land Surface Temperature Data</u>

Land surface temperature data displays temperatures measured on the Earth's surface by artificial satellites (observational satellites). This high-resolution data enables the capture of temperature variations on the Earth's surface.

Data Name	Land Surface Temperature Data (LST)
Data Type	geotiff
For Commercial Use	Available

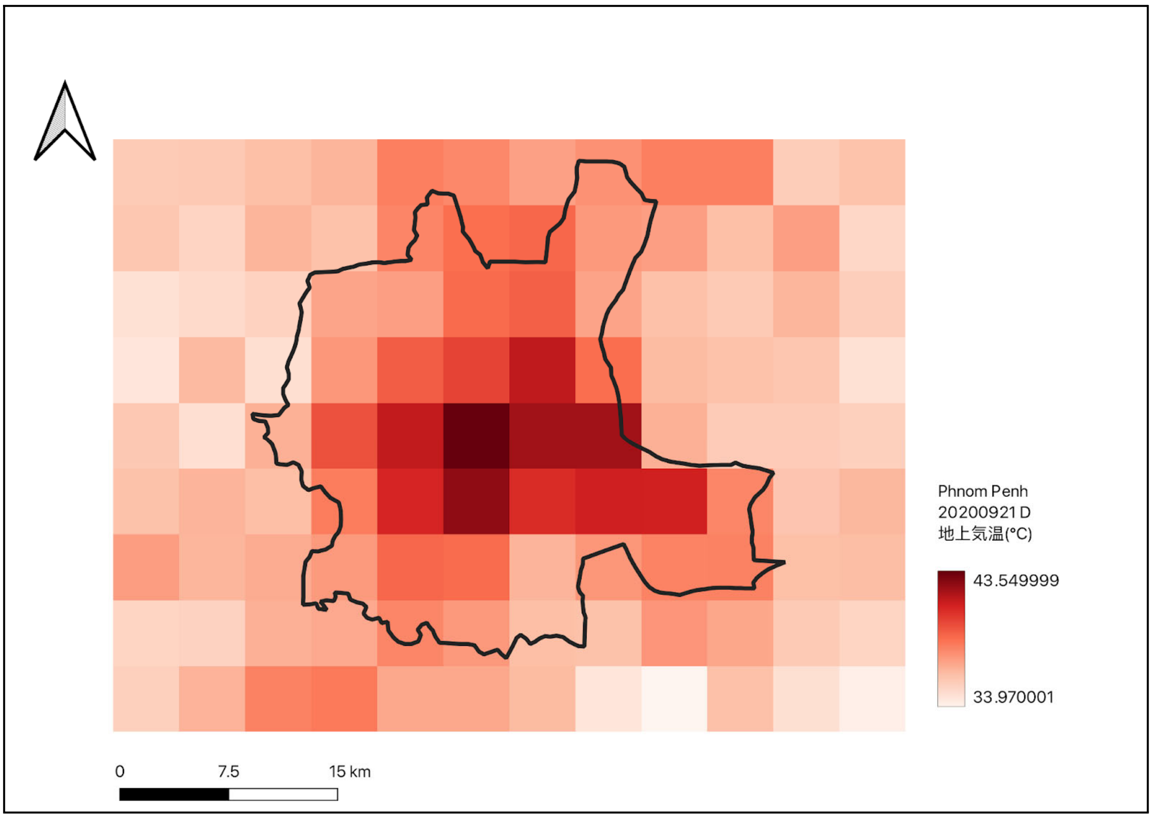


Figure 4-13 Phnom Penh LST Map (21st September 2020)

4.3. Data Utilization

Various types of data utilized for leakage risk assessment are discussed herein. The leakage risk assessment employed the water pipeline and leakage repair data, environmental data, and satellite data as described in Section 4.2. These collected data were formatted to be suitable for analysis.

Regarding the relationship between leakage and various data, a preliminary analysis was conducted for the potential impact of installation year, pipe type, and land use on leakage trends.

Figure 4-14 illustrates the leakage trends by installation year. The horizontal axis represents the installation year, with the lower panel showing a histogram of leakage occurrence (red: leakage present, blue: no leakage), and the upper panel indicating the leakage rate (dashed lines represent the average leakage rate overall. Values above the dashed line suggest a potential association with leakage, while those below suggest no association). The distribution indicates that the majority of water pipelines in Phnom Penh were installed from the early 1990s to the present, with older pipelines exhibiting a higher tendency to leak. It is confirmed that newer pipelines installed after 2010 tend to have fewer leaks.

Figure 4-15 displays the leakage trends by pipe type. The horizontal axis represents the pipe type, and the vertical axis shows a histogram of leakage occurrence in the lower panel and the leakage rate in the upper panel. No significant trend between pipe type and leakage was observed based on the leakage rate.

Figure 4-16 presents the leakage trends by land use. The horizontal axis represents the land use, and the vertical axis shows a histogram of leakage occurrence in the lower panel and the leakage rate in the upper panel. The data used urban land use. Although the original data were classified into 16 categories, they were simplified into four categories for ease of interpretation. Leakage trends were observed in artificial surfaces, while natural and semi-natural areas, agricultural areas, and water bodies exhibited a lower tendency to leak.

From the preliminary analysis using leakage and data utilization as bivariate, it is inferred that installation year influences the leakage risk of pipelines, while although there is no significant difference in leakage risk based on pipe type, areas with a high proportion of artificial structures in urban environments exhibit higher leakage risks from a land use perspective.

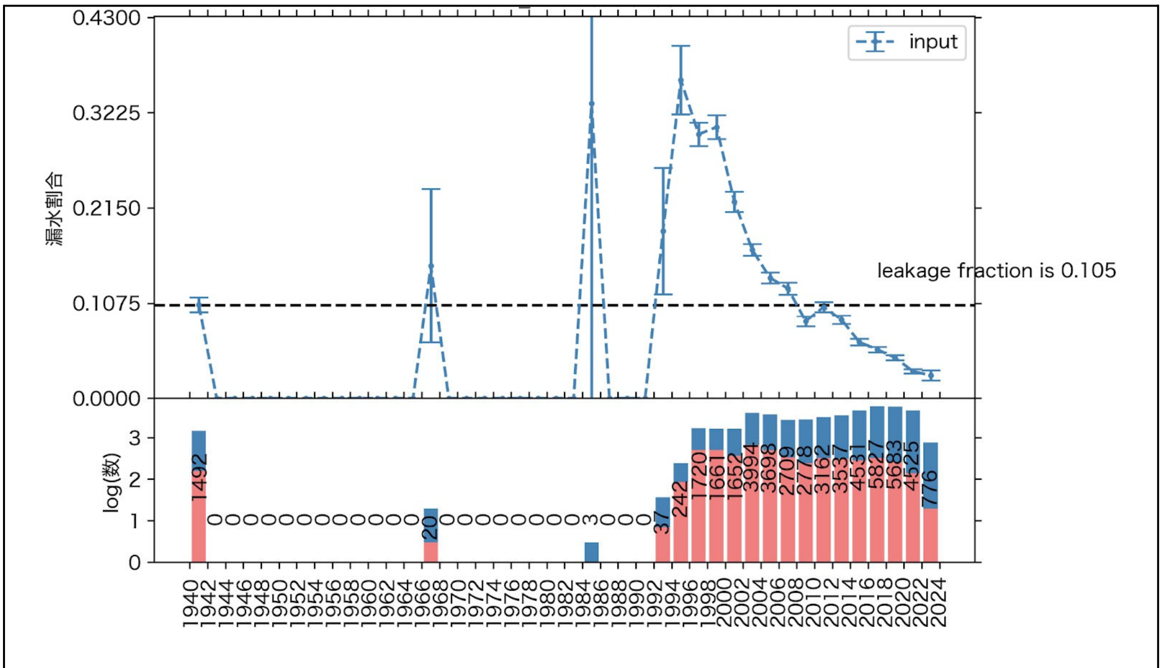


Figure 4-14 Trend of Leakage by Installation Year

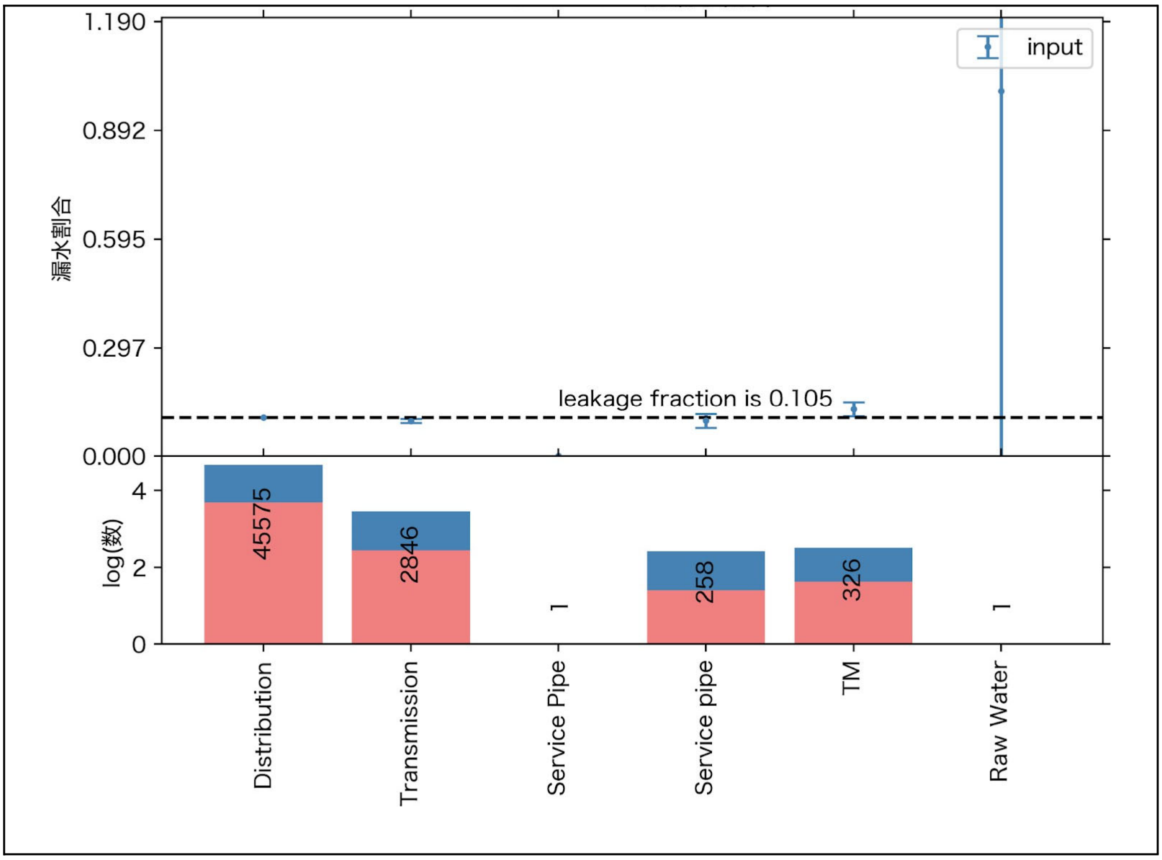


Figure 4-15 Trend of the Leakage by Pipe Material

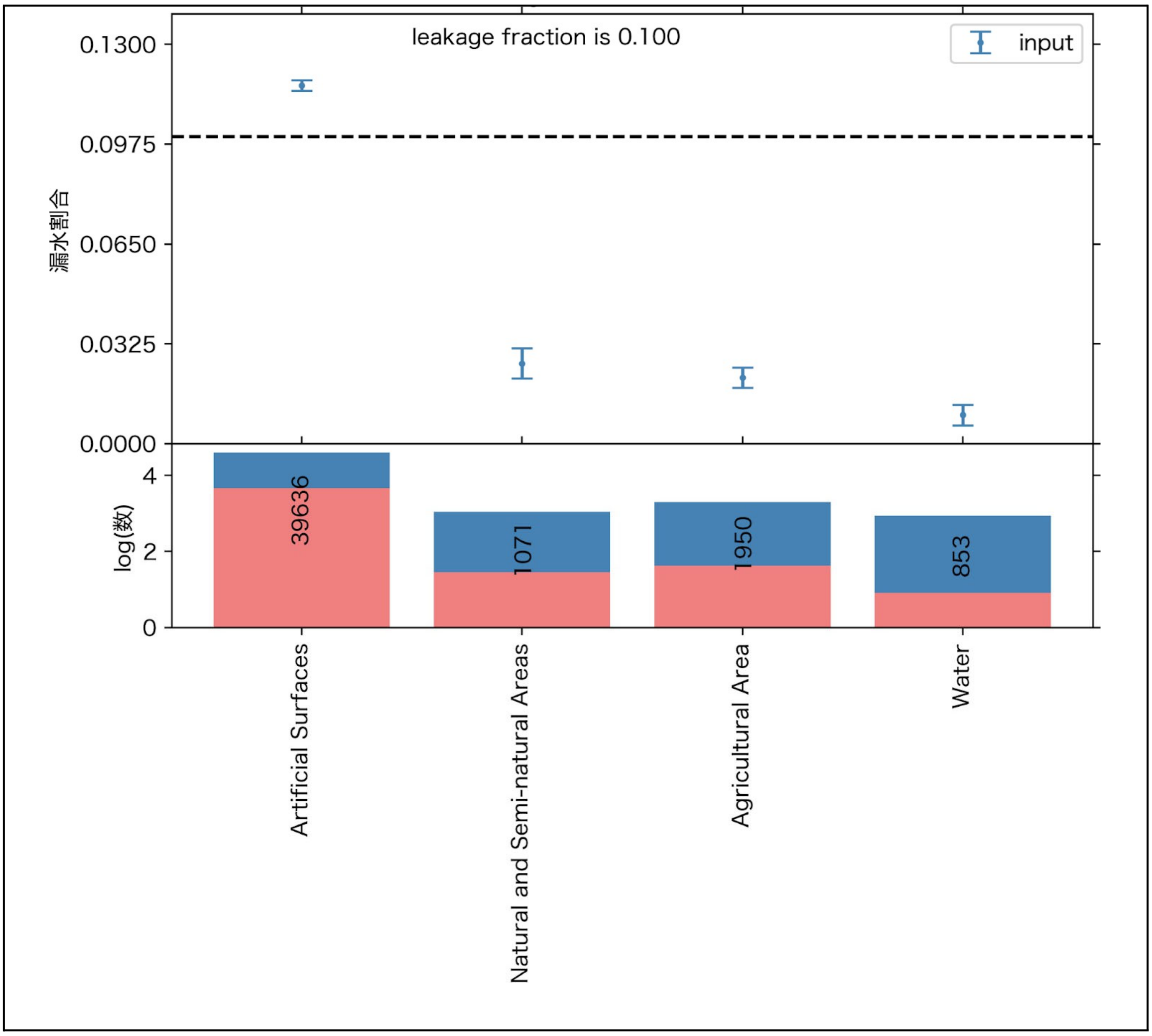


Figure 4-16 Trend of the Leakage by Land Use

4.4. Method

Based on the insights gained from the preliminary analysis in Section 4.3, a high-precision risk assessment model was constructed by applying supervised machine learning capable of representing leakage patterns in high-dimensional data. Supervised machine learning constructs predictive models based on known data to evaluate risks for unknown data.

Here, an analysis approach focusing on pipeline deterioration and load analysis was adopted. Pipeline deterioration is a natural phenomenon where performance decreases over time and may be accelerated by external factors such as physical pressure, chemical influences, and environmental factors (temperature changes, soil types, etc.). Analyzing these factors enables more accurate prediction of leakage risk.

Furthermore, leakage risk was evaluated in five levels based on the leakage probability calculated by machine learning algorithms, with approximately a 100m x 100m mesh, including water pipeline routes, as the smallest unit. Meshes with high risk levels are more likely to experience leakage within the past two years. Particularly, meshes with risk levels 4 and 5 indicate high leakage risk, recommending leakage investigations. Risk assessment aims to efficiently identify areas with high leakage risk, reducing pre-planning and implementation costs for necessary measures.

Figure 4-17 illustrates the relationship between the years of pipeline use (horizontal axis) and leakage risk or probability (vertical axis), visually depicting how leakage risk changes as the pipelines age. The normal degradation curve (green) represents the degradation pattern of pipelines under no special load conditions, while the degradation curve under load (red) illustrates the degradation pattern when pipelines are subject to special loads. This indicates an earlier increase in risk compared to the normal degradation curve.

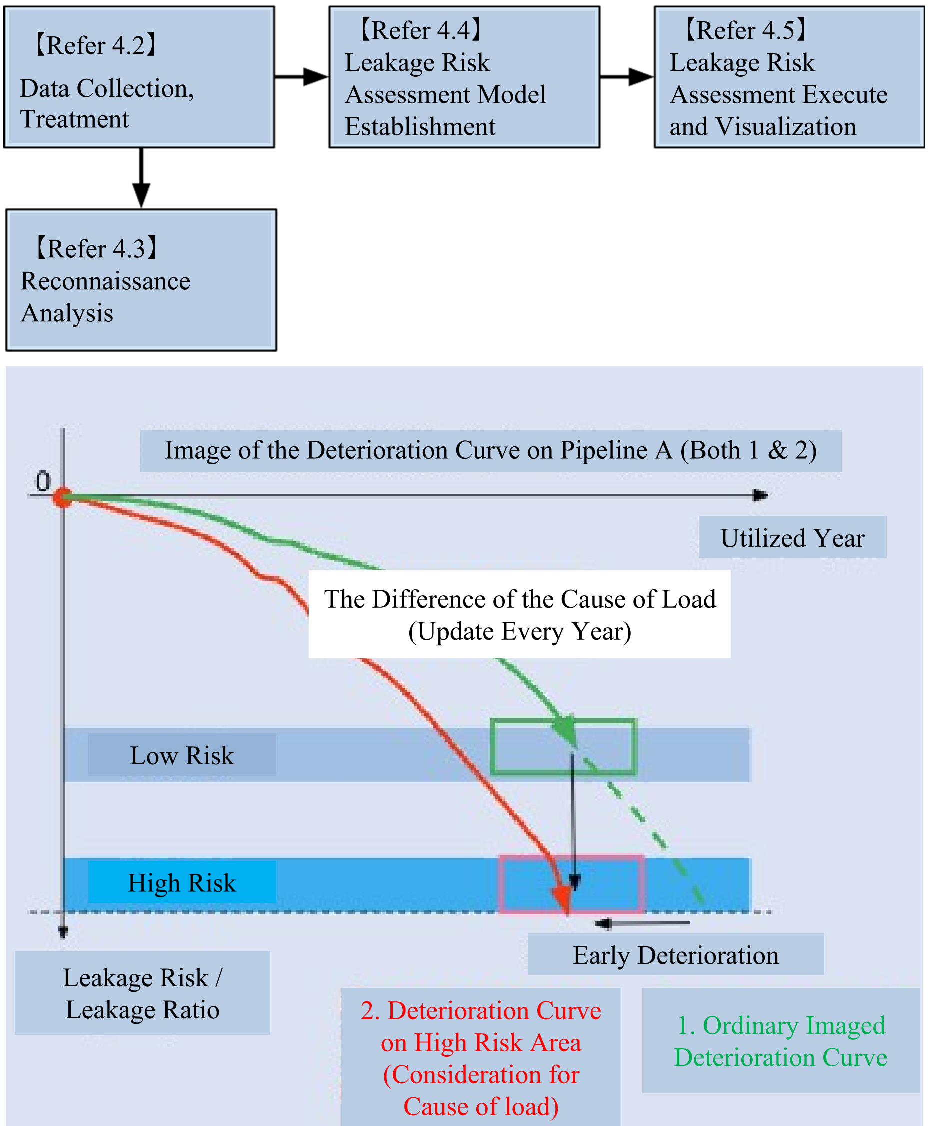


Figure 4-17 Analysis Flow for Leakage Risk Assessment (Upper Side) and Approach of Leakage Risk by Utilized Year of Pipeline (Lawer Side)

4.5. Result

The results of leakage risk assessment in Phnom Penh are presented below. Figure 4-18 shows the administrative areas within Phnom Penh under consideration.

As a result of the leakage risk assessment, the leakage risk in Phnom Penh is shown in Figure 4-19. The correspondence between colors and risks in the figure is as follows: Risk 1 (purple), Risk 2 (blue), Risk 3 (green), Risk 4 (orange), Risk 5 (red). Additionally, Figures 4-20 to 4-21 extract and display the results of high-risk areas, specifically Risk 4 and Risk 5, and Risk 5 only.

Tables 4-10 and 4-11 provide the aggregated results of the number of meshes and the length of pipelines by risk in each administrative area within Phnom Penh. High-risk areas are notably concentrated in Prampir Makara, Tuol Kouk, Chamkar Mon, and Doun Penh, which constitute the central area of Phnom Penh. Calculating the proportion of Risk 4 and 5 meshes to the total number of meshes within the administrative areas reveals that 56% to

83% of meshes in the central area are classified as Risk 4 or Risk 5, suggesting the severity of leakage risk and the urgency of leakage prevention measures.

Furthermore, in Mean Chey, Russey Keo, Chbar Ampov, and Sen Sok, surrounding the central area, the proportion of Risk 4 and 5 meshes to the total number of meshes ranges from 16% to 25%, indicating a mitigated distribution of high-risk areas compared to the central area. Additionally, in Pou Senchey, Prek Pnov, Dangkao, and Chroy Changvar, this proportion ranges from 3% to 15%, suggesting relatively lower leakage risks in these regions.

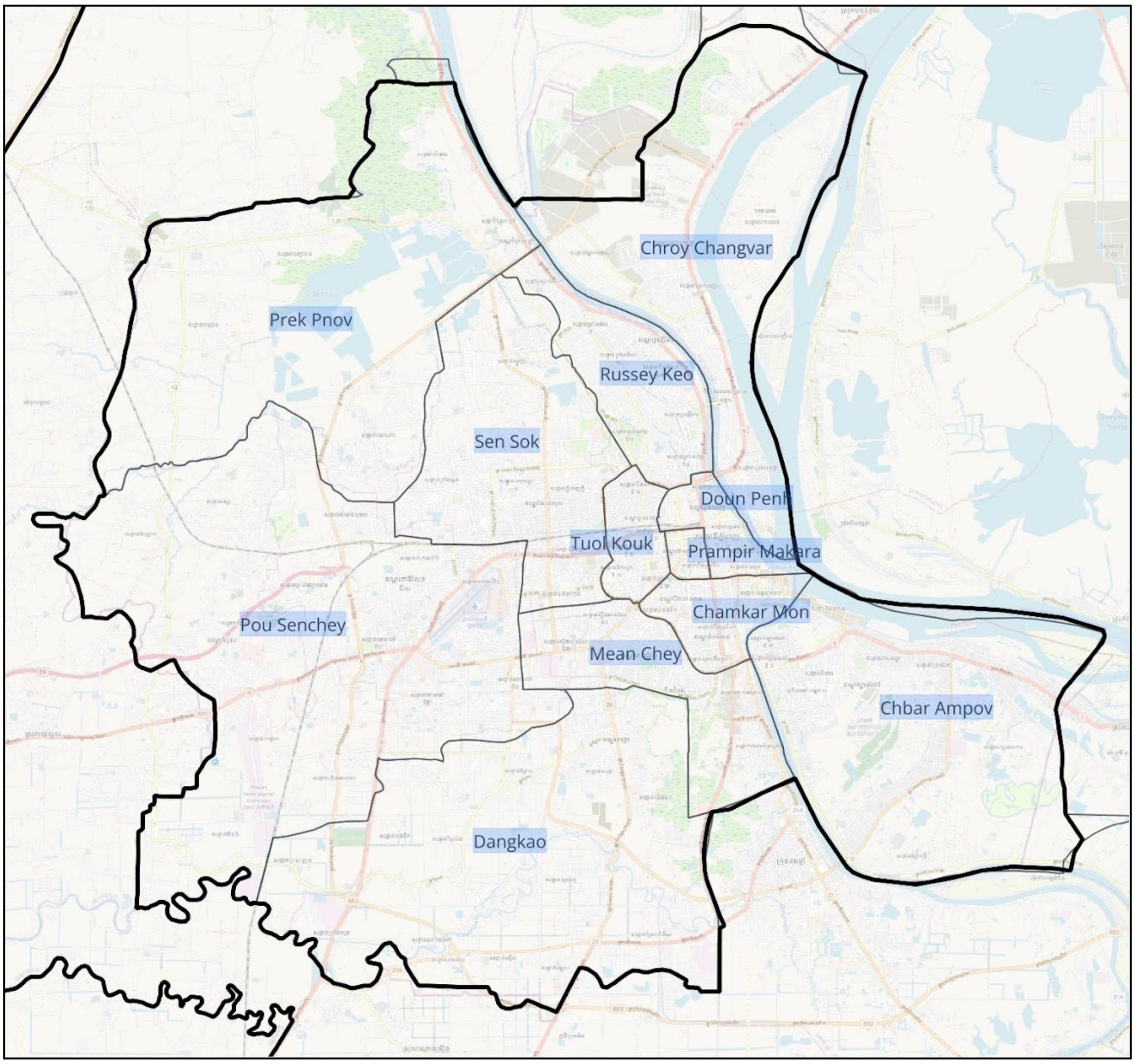


Figure 4-18 Administrative Border of Phnom Penh

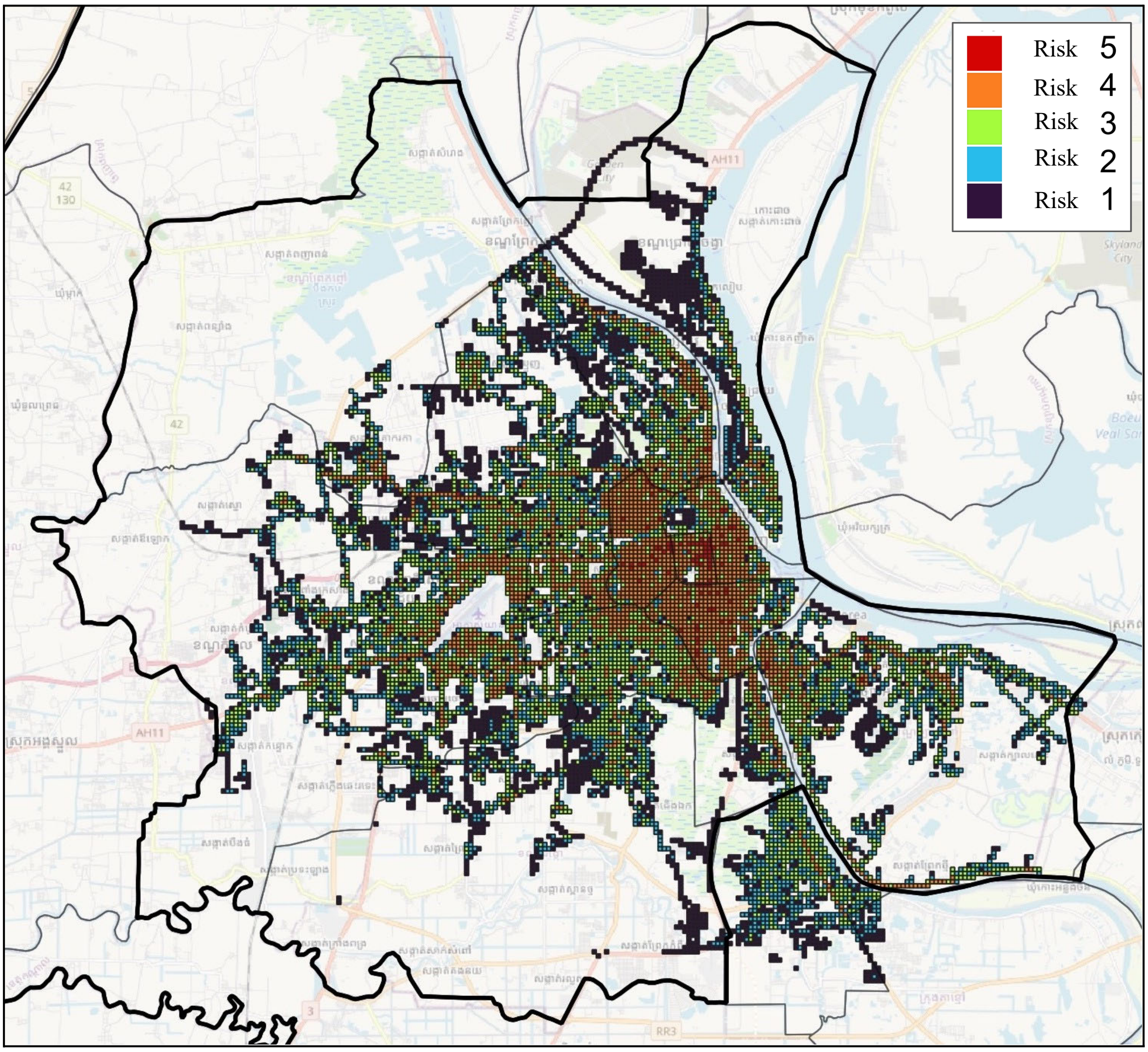


Figure 4-19-1 Assessment of the Leakage Risk in Central Phnom Penh

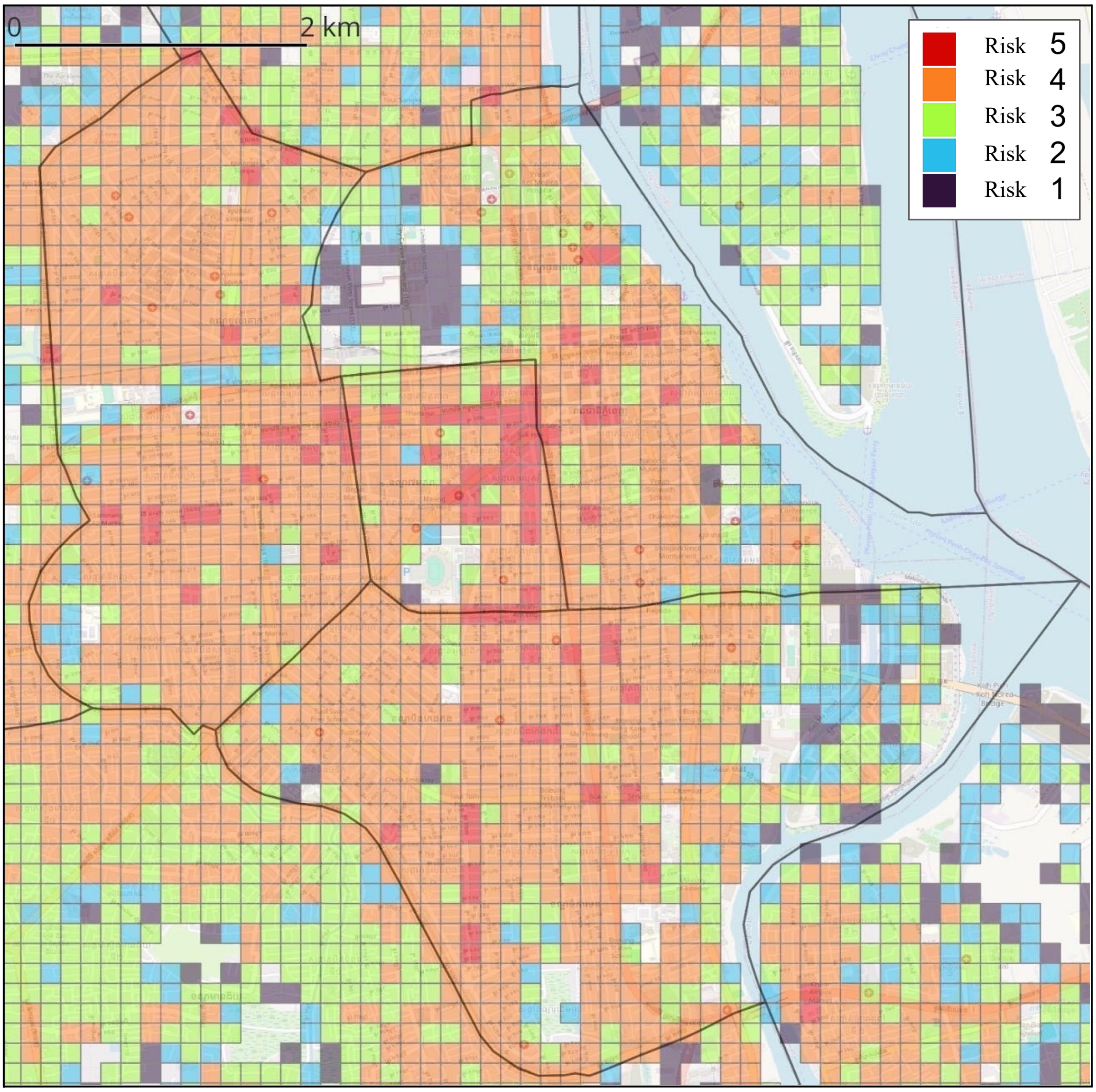


Figure 4-19-2 Zoom-Up Figure Around Prampir Makara

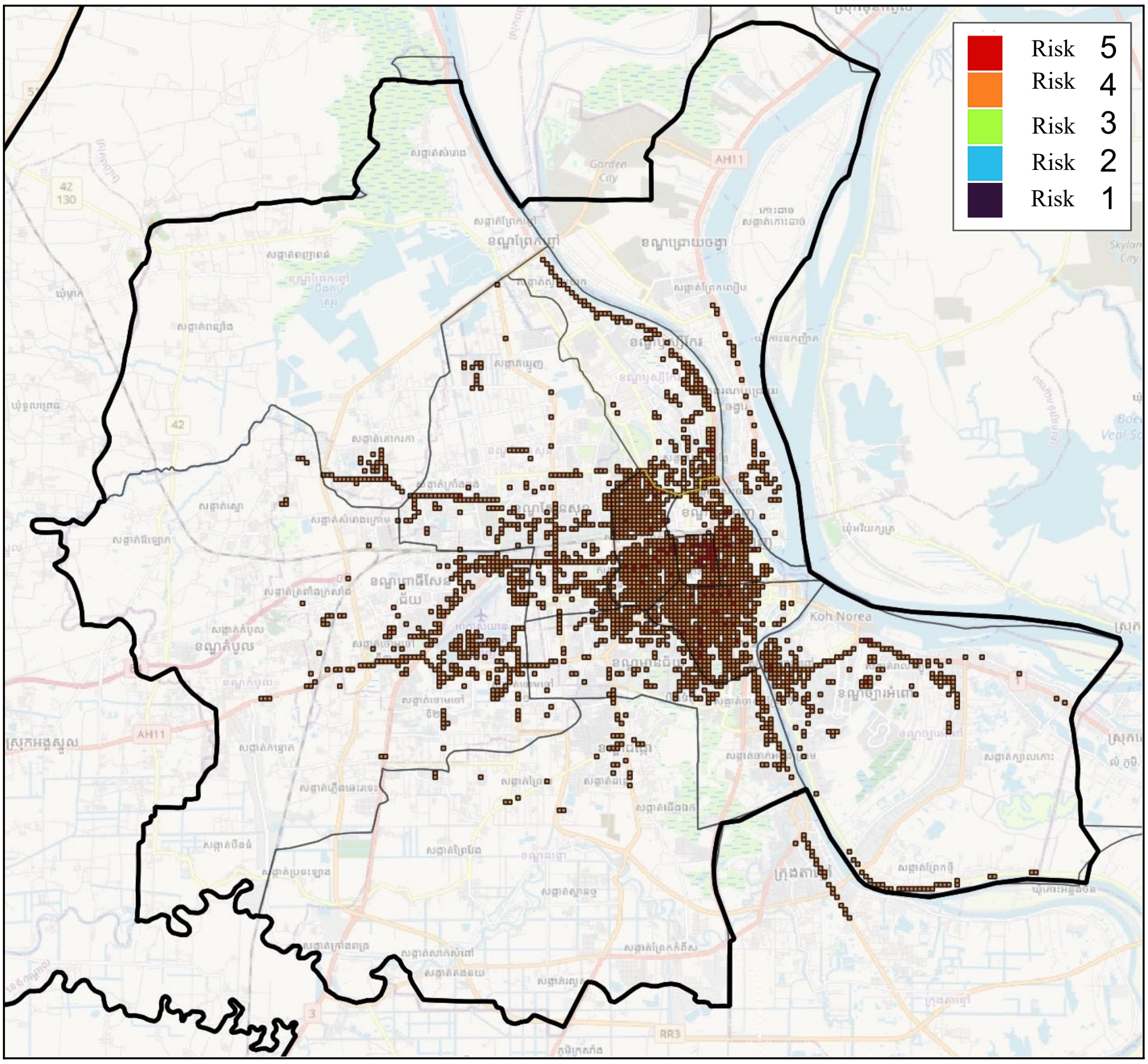


Figure 4-20-1 Assessment of Leakage Risk in Phnom Penh (Only Risk 4 and 5)

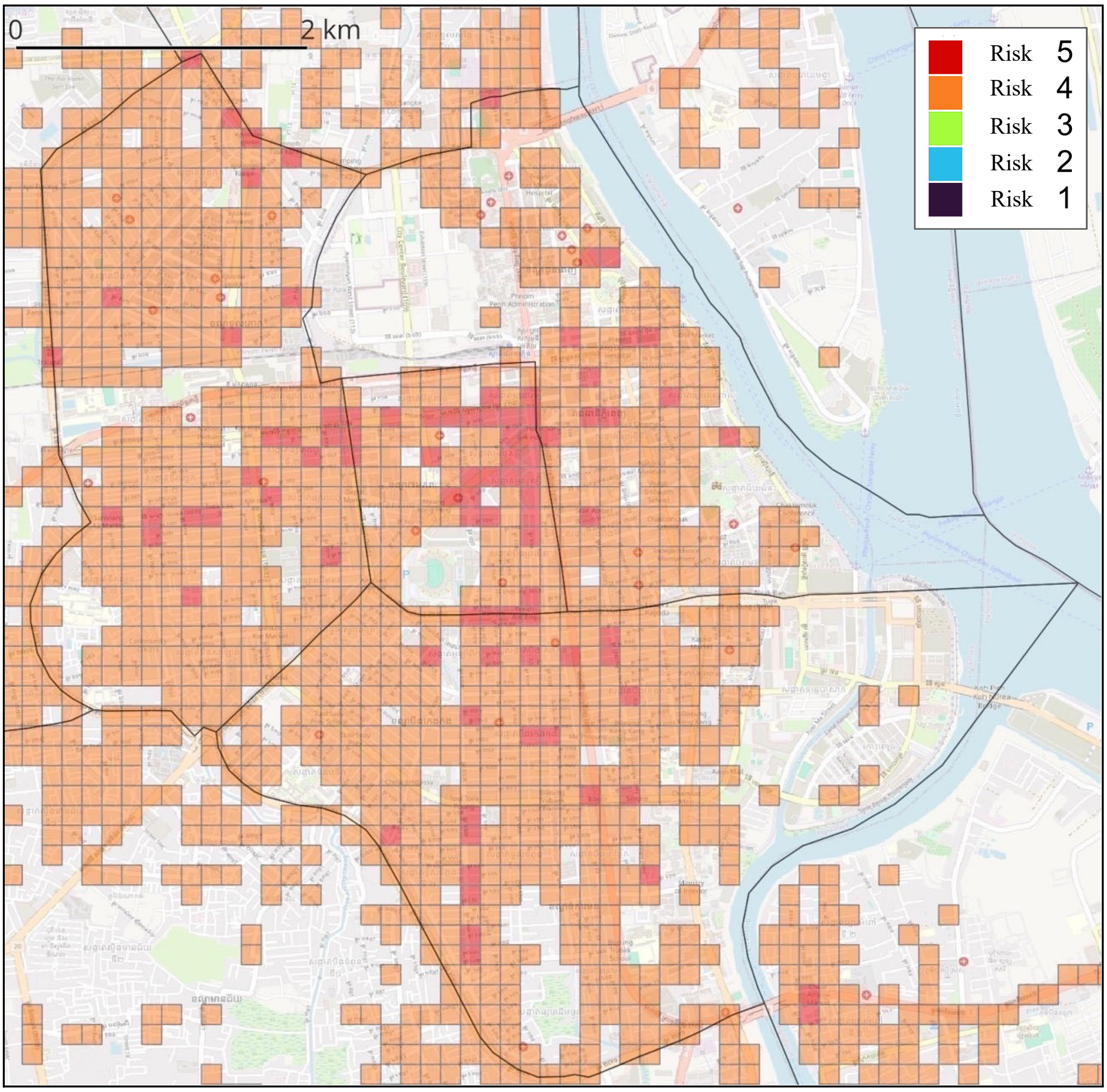


Figure 4-20-2 Zoom-Up Figure Around Prampir Makara (Only Risk 4 & 5)

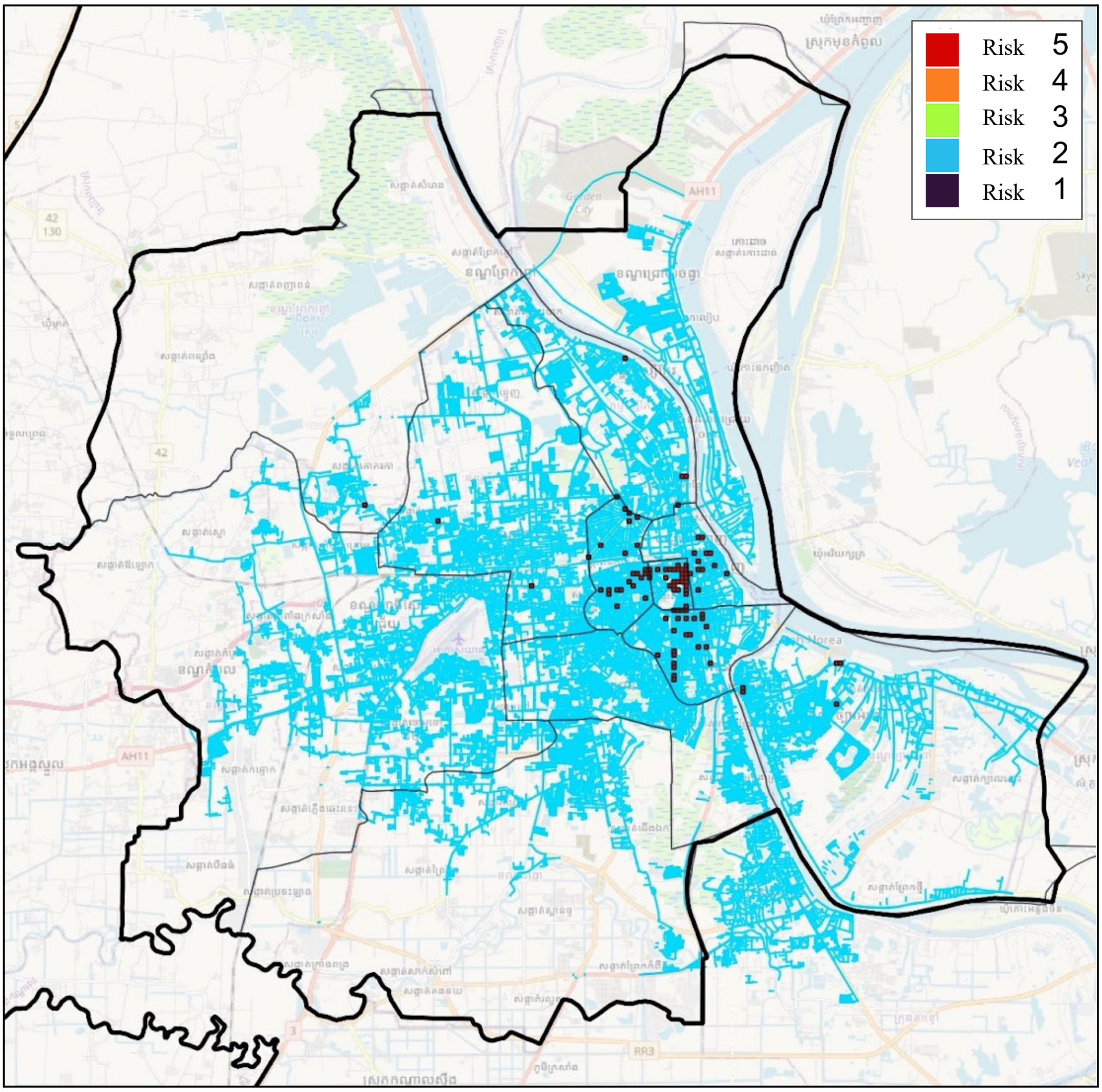


Figure 4-21-1 Assessment of the Leakage Risk in Phnom Penh (Only Risk 5, Blue: Pipeline)

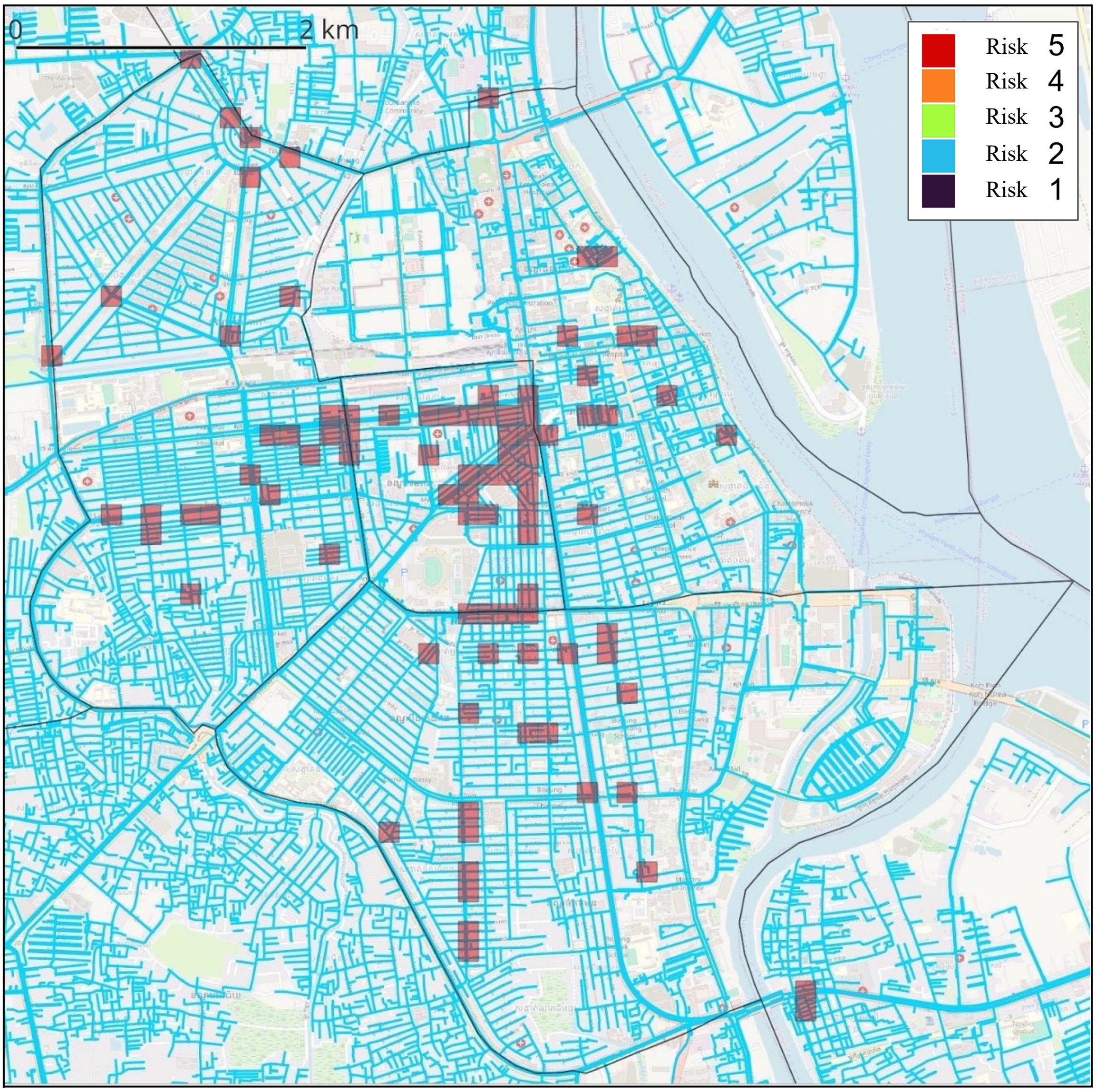


Figure 4-21-2 Zoom-Up Figure Around Prampir Makara (Only Risk 5, Blue: Pipeline)

Table 4-10 Mesh Number by Area & Risk

Area Name	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Prampir Makara	1	2	16	63	27
Tuol Kouk	1	19	54	316	24
Chamkar Mon	15	48	89	307	24
Doun Penh	26	23	71	142	11
Mean Chey	153	133	462	247	0
Russey Keo	217	173	296	177	4
Chbar Ampov	260	365	504	203	5
Sen Sok	452	353	636	295	4
Pou Senchey	623	573	829	323	0
Prek Pnov	83	64	63	36	1
Dangkao	522	240	245	35	0
Chroy Changvar	448	126	147	48	0

Table 4-11 Pipe Length by Area & Risk (m)

Area Name	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5
Prampir Makara	35	286	3,989	32,153	21,433
Tuol Kouk	220	1,895	12,692	144,992	18,675
Chamkar Mon	2,115	9,508	27,922	134,779	16,569
Doun Penh	6,380	5,748	17,923	60,755	8,358
Mean Chey	36,644	31,530	191,183	137,112	0
Russey Keo	43,571	47,497	105,564	93,958	3,583
Chbar Ampov	41,220	74,300	190,073	98,260	5,199
Sen Sok	92,399	79,610	243,563	161,629	3,377
Pou Senchey	131,301	134,319	316,665	178,708	0
Prek Pnov	15,786	14,873	19,258	18,402	518
Dangkao	139,325	73,341	112,423	23,234	0
Chroy Changvar	115,555	27,019	42,722	23,404	0

4.6. Analysis of Empirical Results and Challenges

The analysis of the leakage risk assessment model using supervised machine learning algorithms suggests that the primary factors influencing leakage risk are the length of pipelines, installation year, diameter, land use, population density, and surface temperature (Table 4-12). Information obtained in this study, such as the material and age of the pipelines, as well as changes in land use, population, and temperature, indicates their influence on pipeline deterioration. Additionally, information such as soil quality and groundwater levels at pipeline locations, which are scientifically considered to affect pipelines, could further enhance the effectiveness of the analysis.

To compare the top three major factors influencing leakage risk, we conducted a comparison between high-risk and low-risk meshes. Here, we aggregated Risk 4 and 5 as high-risk and Risk 1, 2, and 3 as low-risk. Figure 4-22 illustrates a comparison of pipeline lengths for lengths less than 1,000m. Both high-risk and low-risk meshes exhibited generally similar trends. Figure 4-23 depicts a comparison of installation years from 1990 to 2023. Older installation years corresponded to higher-risk meshes, while newer installation years were associated with lower-risk meshes. Figure 4-24 shows a comparison of pipeline diameters for diameters less than 400mm. High-risk meshes were slightly more prevalent in the diameter range of 170mm to 330mm.

Table 4-12 The Primary Factors Influencing Leakage Risk Assessment

Factor	Importance	Interpretation
Pipe Length	High	In the evaluation units of 100m mesh, it is believed that the longer the pipes contained within, the greater the number of joints, which can impact the leakage risk from the perspective of joint strength.
Install Year	High	Deterioration over time, such as material degradation of pipelines and loosening of connections, is considered a contributing factor.
Diameter	High	Preliminary analysis indicates that most leaks occur in pipe diameters of approximately 100mm to 200mm. This is because smaller diameters are inherently more fragile and susceptible to environmental influences.
Land Use	High	Areas with a high density of artificial structures in urban regions tend to exhibit a propensity for leaks. This is attributed to increased usage of pipelines and environmental stress accompanying urbanization.
Population Density	Middle	Regions with high population densities may experience increased strain on the water system, leading to higher leakage risks.
Grand Surface Temperature	Middle	High temperatures (e.g., above 40°C) as well as temperature differentials and fluctuations are believed to influence leakage risks.
Other Factor	Low	Other factors such as slope angle, burial depth, elevation, and road functional classification may also play a role.

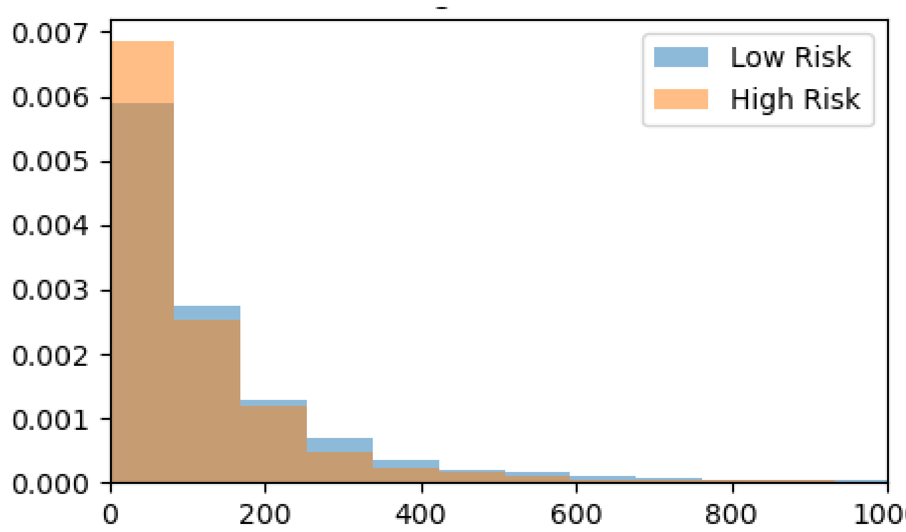


Figure 4-22 The Comparison of the High Risk Mesh & Low Risk Mesh by Pipe Length

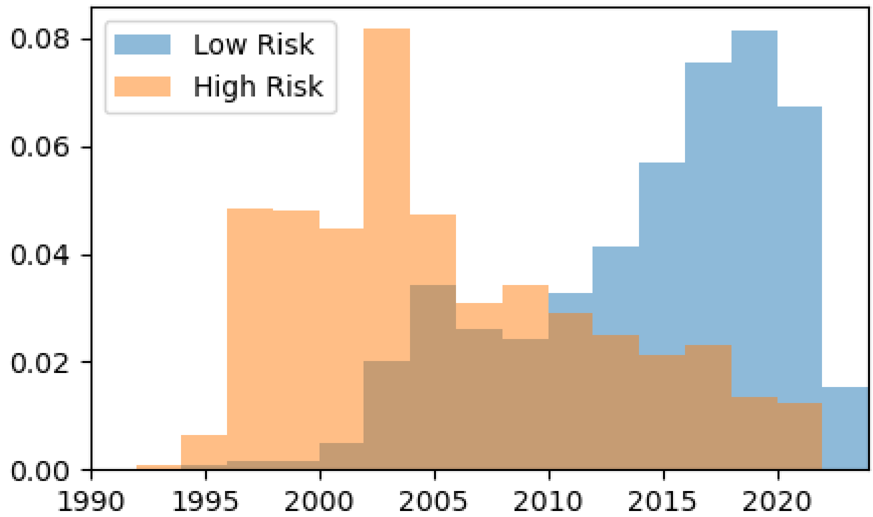


Figure 4-23 The Comparison of the High Risk Mesh & Low Risk Mesh by Install Year

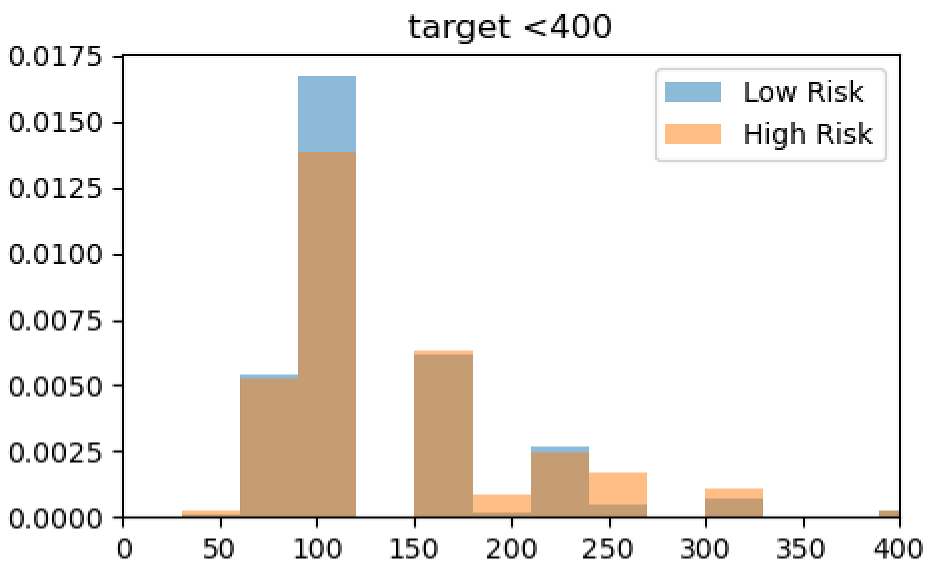


Figure 4-24 The Comparison of the High Risk Mesh & Low Risk Mesh by Diameter

Based on the analysis of this leakage risk assessment model, a leakage risk assessment was conducted in Phnom Penh. The leakage risk was evaluated on a five-point scale, identifying areas of high and low risk (Figure 4-19-1 & 4-19-2). High-risk areas (Risk 4 and Risk 5) were concentrated in the city center (Prampir Makara, Tuol Kouk, Chamkar Mon, Doun Penh), while the peripheral areas of the city center (Mean Chey, Russey Keo, Chbar Ampov, Sen Sok) exhibited moderate risk, and further outlying areas (Pou Senchey, Prek Pnov, Dangkao, Chroy Changvar) showed low risk. As a result, it suggests the urgency for leakage investigation and infrastructure renewal in areas where high risk is concentrated. An action plan based on the leakage risk assessment involves allocating resources to visualized high-risk areas in advance, with the expectation of early leakage detection, streamlined leakage investigation, and optimization of long-term water infrastructure renewal plans.

Furthermore, to properly evaluate the analyzed risk values, it is necessary to compare them with on-site investigations regarding the presence of leaks in Phnom Penh. As an example, Figure 4-25 illustrates the comparison between the analyzed risk values and on-site investigations of leak presence conducted using similar methods to those employed in this study in local municipalities in Japan. This figure evaluates how efficiently each scenario can detect leaks within a specific period. The horizontal axis represents the number of mesh units, while the vertical axis indicates the percentage of leaks detected. The investigation scenarios are as follows: (1) Blue indicates investigation in order of highest-risk areas based on the analysis results, (2) Green represents investigation in order of oldest installation years, and (3) Black signifies random investigation. If approximately 1800 mesh units were surveyed, scenarios (3) and (2) respectively resulted in leak detection rates of 14.6% and 33.2%, while scenario (1) achieved a detection rate of 55.1%, demonstrating a higher cost-effectiveness.

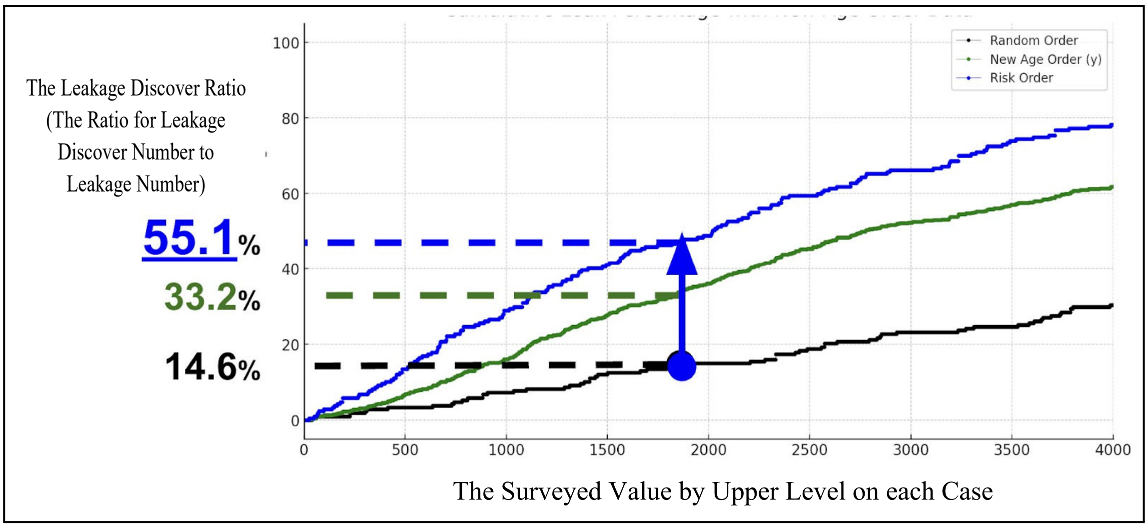


Figure 4-25 Benefit Per Cost Based on Three Scenarios

The analysis of the water supply pipeline data in Phnom Penh provided sufficient information for conducting leakage risk assessment, despite the fewer items of information compared to Japanese municipalities. Furthermore, it became evident that the leakage repair data, with a sufficient history of occurrences, proved useful in evaluating leakage risks. These repair data include information on leakage factors, enhancing the accuracy of risk assessment.

Environmental data, including terrain, soil, land use, and population density, were sufficiently maintained as part of global datasets and were accessible. However, the update frequency of these environmental data may not be high enough to adequately address significant urban changes, such as those in Phnom Penh. Supplementary measures such as satellite data or satellite-based land cover classification and soil data could be considered to complement these environmental datasets.

Satellite data, being accessible regardless of national or regional boundaries, provided sufficient information for this task. Overall, it was confirmed that there is ample data available for conducting leakage risk assessment in Phnom Penh.

Considering the current state of data management in Phnom Penh, the introduction of GIS leakage risk management services could serve as a model case for data-driven leakage risk management promoted by Phnom Penh City's DX initiative. In the DX initiative, efficient workflow and systems connecting data collection to analysis and decision-making based on analysis results are crucial. For instance, real-time accumulation of information from field surveys and repairs via input devices facilitates continuous monitoring and evaluation, streamlining water infrastructure maintenance and enabling long-term infrastructure development.

Some GIS leakage risk management services can operate with just a browser and an internet connection, allowing various stakeholders within Phnom Penh City (local municipalities, support organizations, subcontractors, city residents, etc.) easy access. Furthermore, these systems possess scalability for customization and service expansion according to urban growth, flexibly adapting to future changes in demand.

Among the GIS leakage risk management services, there are platforms that comprehensively manage various services tailored to user needs, such as monitoring water areas (dams, rivers, etc.) relevant to water supply systems and identifying suitable locations for wind power generation facilities or solar panel installations.

The approach of visually representing leakage risk assessment results on maps (Figures 4-19-1 & 4-19-2) is commonly used domestically and is effective in enhancing understanding of leakage risks. However, it is necessary to determine the most effective output format for PPWSA. PPWSA needs to understand the needs and conditions for using future leakage risk management tools and provide a user interface that meets these requirements.

In parallel, to maximize the effectiveness of introducing leakage risk management services, it is essential to assess PPWSA's technical and financial capacities and customize them as needed. Technical capacity includes proficiency in GIS software operation and data analysis, while financial capacity includes budgetary requirements for tool maintenance and updates. Additionally, continuous leakage risk assessment and periodic updates of water supply pipeline data and leakage repair data are indispensable to maintain the analysis results up to date. Managing these data appropriately and ensuring the capacity to regularly update and share them may require reinforcement as necessary.

By regularly collecting and analyzing data, it is possible to update the correct dataset for supervised machine learning algorithms. Regularly updating the results enhances the reliability of the analysis results and maximizes their utilization. Therefore, it is necessary to continuously record the analyzed data to control risks such as human input errors or data deletion. It is also essential to record soil data, such as regional vibration data or soil data collected during pipeline installation, which directly affect pipelines. Analyzed leakage risks can be utilized for future pipeline improvement plans, allocation of repair materials within responsible water supply areas, and organization planning for repair teams. Data collection of this nature should be integrated into daily activities and recorded, and managing them on GIS allows smooth and effective implementation of analysis using machine learning algorithms in the future.

5. Conclusion

Lastly, it is crucial to consider the anticipated needs and challenges during and after the implementation of the Niroth Water Supply Expansion Project. As this project progresses, new water supply pipelines will be installed, and integration with existing pipelines may change parameters and priorities for leakage risk assessment. Flexibly adapting to such changes and adjusting the leakage risk assessment methodology as needed will be crucial for effective leakage management.

In conclusion, this task demonstrated the feasibility of conducting leakage risk assessment in administrative areas of Phnom Penh. The analysis of the demonstrated leakage risk assessment model identified pipeline length, installation year, diameter, land use, population density, and surface temperature as significant factors influencing leakage risks. This analysis also enabled the identification of high and low-risk areas in Phnom Penh. Overall, it was confirmed that there is sufficient data available to conduct leakage risk assessment in Phnom Penh.

Thanks to KWS's collection, adjustment, and provision of water supply pipeline and leakage repair data, Tian Di Ren was able to complete this task in approximately four months. Additionally, thanks to KWS's sharing of various data insights, Tian Di Ren was able to smoothly progress with this task.

ANNEX 12 THE DEVELOPMENT OF ROADMAP FOR THE ESTABLISHMENT OF WQC

CHAPTER 1 BACKGROUND AND PURPOSE OF THE STUDY

1.1 Background of the Study

In February 2003, the Royal Government of Cambodia announced the “National Policy on Water Supply and Sanitation”, which aims to "ensure that the people of Cambodia receive a safe water supply, have sanitation facilities, and enjoy a safe, hygienic, and environmentally adapted living environment," and is promoting the development of the water supply sector based on this policy. In Phnom Penh, the country's capital, the Phnom Penh Water Supply Authority (PPWSA) is responsible for water supply services. As a result of the efforts of the government of Cambodia and the authorities of Phnom Penh, as well as effective support from Japan and many other countries and organizations, the current water supply rate has reached over 90%, and 24-hour water supply has been realized in those areas.

PPWSA has established a Water Laboratory to test the quality of the water supply throughout the water supply area for the purpose of ensuring the safety of the water quality to be supplied. The water quality laboratory selects items to be measured based on the National Drinking Water Quality Standards (NDWQS), which were revised in 2015 by the current Ministry of Industry, Science, Technology, and Innovation (MISTI), and set, as well as the appropriate frequency of water quality measurements (frequency of water sampling), although four of the water quality items specified in the water quality standards are not measured. This is due to the fact that the analytical instruments required to measure the four water quality items, including barium and cadmium, are not in place. In addition, even for the water quality standard items that are measured, their measurement methods may differ from the methods indicated in the water quality standards.

In response to this situation, PPWSA would like to establish a Water Quality Center (WQC) with appropriate equipment to analyze all items of the NDWQS, and in addition to PPWSA's measurement of all items of the water quality standards, PPWSA would like to establish a system to respond to customer needs regarding water quality and emergency situations such as abnormal water quality. However, since there is no such comprehensive testing facility for drinking water quality in Cambodia, and the information available for developing a roadmap for the establishment of the WQC is limited, a request was made to Japan for cooperation in developing a roadmap for the establishment of such a water quality testing center.

The PPWSA has informed of this request in the process of the "Preparatory Survey on the project for expansion of the Nirodh water treatment plant in Cambodia". In addition, the improvement of water quality analysis capacity was proposed in the report of “The data collection survey on water supply development in Phnom Penh capital in the Kingdom of Cambodia: final report. -, (February 2022)”[1] proposed. In addition to this, the fact that addressing water quality concerns is essential for the region to continue to develop, that it is important to establish an advanced water quality center and expand the parameters to be monitored, and that immediate human resource development is needed led to a roadmap development study for the establishment of the WQC.

1.2 Purpose of the Study

The Water Laboratory at PPWSA is responsible for measuring water quality in raw water and drinking water treatment, as well as testing water quality to ensure the safety of the water supply. Although the Water Laboratory operates in accordance with the NDWQS, it does not have a measurement system in place for the four items specified in the water quality standards: barium, cadmium, lead, and mercury, and its methods for measuring multiple water quality items do not comply with the methods indicated by the NDWQS. This

[1] The data collection survey on water supply development in Phnom Penh capital in the Kingdom of Cambodia: final report. -, JICA, (2022)

study investigates the development of a roadmap for the establishment of a WQC with a system that can resolve these issues mentioned above and quickly confirm the safety of water quality in the event of an emergency, such as a water quality accident at the water source or in the water distribution/supply process.

1.3 Scope of Survey

In order to achieve the above objectives, the following shall be investigated and a report including a roadmap for the establishment of the WQC shall be prepared and submitted to PPWSA after explanation and discussion.

1. Review of current status of PPWSA Water Laboratory
2. Identifying Issues for PPWSA Water Laboratory
3. Process of establishment of water quality centers in Japanese water utilities and surrounding conditions.
4. Case study of the establishment of a water quality center in a country surrounding Cambodia

CHAPTER 2 COOPERATION WITH PARTNERS OF ADVANCED COUNTRY

2.1 Tap Water Safety and Water Quality Tests

The World Health Organization (WHO) states that safe drinking water is essential for people to live healthy lives, and the Guidelines for drinking-water quality set by the WHO provide guideline values for safe drinking water[2]. Many countries have established their own water quality standards based on these drinking water quality guidelines, according to the actual conditions in each country. In addition, to demonstrate that the water is safe to drink, many countries require water quality test to ensure that the quality of the supplied water meets the water quality standards of the respective country.

The NDWQS was revised in 2015 and, along with compliance with water quality standards, requires organizations that supply water to test the quality of the water supply. There are various techniques for testing water quality, ranging from simply immersing the detection part of a simple testing device in the test water to obtain results, to applying extremely complex and sophisticated techniques to pretreat the test water, followed by measurement with sophisticated analytical equipment. Recently, as a result of the runoff of artificially synthesized chemical substances such as pesticides into the environment, the number of substances set as water quality standards has increased, and the concentrations set as standards or guideline values have become extremely low. This has necessitated the use of sophisticated analytical instruments for water quality test and the need to secure personnel who have acquired the knowledge and skills to use these instruments. As a result, it is taking longer and costing more cost to develop an organization to test water quality than in the past. In addition, the purchase and maintenance of equipment requires significant expense, and it is estimated that water quality test is a major challenge for sanitation administrations and water supply authorities in countries that are not financially affluent.

2.2 Past Support of Water Quality Management for PPWSA

This section summarizes the assistance provided to the PPWSA, including technical assistance obtained to establish the current water quality management system. Summary of cooperative assistance from other countries and development organizations compiles based on the report of “The data collection survey on water supply development in Phnom Penh capital in the Kingdom of Cambodia: final report –”[3]. PPWSA has received assistance from the World Bank, Asian Development Bank, Japan, and the European Investment Bank, as well as France and its affiliated agencies. In all the cases, the focus seems to be on construction and expansion of water supply facilities, and no direct PPWSA assistance for water quality testing and its facilities has been identified, except for Japanese assistance for human resource development. During the onsite interviews, it was not confirmed that there was an actual result of direct assistance for water quality test and its facilities, except in the relevant case of Japan.

2.2.1 Japan's Support for Water Quality Test

(1) Japan's Track Record of Assistance to the PPWSA

Japan has provided PPWSA with technical cooperation projects, grant aid projects and loan aid projects[4]. An overview of these projects is shown in the below.

1) Technical cooperation projects
・“Human resource development project in waterworks” (2003～2006)

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[2] Guidelines for drinking-water quality, WHO,
[3] The data collection survey on water supply development in Phnom Penh capital in the Kingdom of Cambodia: final report. -, JICA, (2022)
[4] Preparatory survey on the project for expansion of Phum Prek water treatment plant in Cambodia, JICA, (2022),

2) Technical cooperation projects of development plan study type
・“The study on Phnom Penh water supply system in the Kingdom of Cambodia”, (1992～1993)
・“The study on Phnom Penh water supply system in the Kingdom of Cambodia, phase 2”, (2004～2005)

3) Loan aid projects
・“The study on the development plan of Nirodh water treatment plant”, (2008 ～2013)

4) Grant aid projects
・“The study on Phnom Penh water supply system in the Kingdom of Cambodia”, (1993～1994)
・“The study on Phnom Penh water supply system in the Kingdom of Cambodia, phase 2”, 1997～1999)
・“The study on water supply expansion project of Phum Prek water treatment plant in the Kingdom of Cambodia”, (2000～2003)

Among these assistance projects, direct support for the substantive work of water quality test conducted by PPWSA was provided by the Technical Cooperation Project "Human resource development project in waterworks," which was implemented from 2003 to 2006. The similarly named " Human resource development project in waterworks phase 2" and " Human resource development project in waterworks phase 3" were conducted for local public waterworks authorities from 2007 to 2011 and 2012 to 2017 respectively, and the project for the PPWSA is considered to be as “phase 1”.

(2) Details of Assistance to PPWSA's Water Quality Testing Operations under the "Human resource Development Project in Waterworks "

The "Human resource development project in waterworks" was implemented from October 14, 2003 to October 13, 2006[5] in four areas: "maintenance and management of water distribution pipes," "water quality management," "maintenance and management of electrical equipment," and "water treatment technology including machinery. One of the outcomes of the project is that "3. The PPWSA's water quality analysis capacity will be improved and a monitoring system will be established." is listed. Reference 4 describes the number of items that can be analyzed for water quality at the end of the project as follows, and it can be estimated that water quality analysis technology has begun to take root in the PPWSA laboratories.

・“Water quality analysis is performed for 33 to 37 parameters, including highly accurate analysis of three parameters: color, free chlorine, and E. coli. In the future, it is planned to increase the number of parameters for high-precision analysis from 3 to 12."

The report also confirms that the results of water quality monitoring are being used for water quality control at water treatment plants and water distribution areas. The results of these efforts are considered to have led to the establishment of the current water quality management system and water quality testing system at water treatment plants and other facilities in the PPWSA.

2.2.2 Support Needed to Make PPWSA's Water Quality Testing System More Accurate and Precise than the Current System

In general, the elements necessary to establish a more advanced water quality testing system can be summarized in the following three points.

・Personnel who have an understanding and knowledge of advanced analytical methods, are proficient in sample preparation and operation of state-of-the-art analytical instruments, and are able to maintain and manage analytical instruments.
・Advanced analytical instruments for precise analysis, equipment, and facilities for conducting inspections
・Costs to secure and maintain necessary personnel and analytical instruments and facilities

The first of these three, which is the most difficult to secure, is human resources with appropriate skills. In

[5] Final evaluation report on the project of human resource development for water supply in Cambodia, (Japanese language only), JICA, (2006),

order to develop human resources, an environment for acquiring knowledge and skills is necessary, and a long time is required. The environment for training personnel must include the following: (1) the facility must have an advanced testing system that is to be established, (2) the chemical items to be tested and their concentration levels must be almost the same, and (3) the quality of the samples to be analyzed (e.g., types and concentrations of coexisting substances other than the chemical items to be tested) must be almost the same. There are not many facilities for training water quality testing personnel with these requirements, and examples of such facilities include only facilities of water utilities that conduct advanced water quality testing and technical centers of manufacturers that produce and sell analytical instruments used in water quality testing. Of these facilities, those that can include training, including on-the-job training, in the development of human resources are limited to water utilities. In other words, in order for PPWSA to train personnel for an advanced water quality testing system, support from overseas water utilities that have already established an advanced water quality testing system is necessary, and PPWSA will seek an international support framework from foreign aid agencies. For these reasons, the most necessary support for PPWSA to establish a WQS at an early stage is the training of personnel skilled in the operation of the latest analytical instruments, etc., and the provision of an appropriate environment for their training.

CHAPTER 3 SURVEY RESULTS OF CURRENT STATUS

3.1 Reaffirming the Need for A Water Quality Center

Access to safe drinking water is essential for human life. The Government of Cambodia has set a goal of ensuring access to safe water for 100% of the urban population by 2025 through the “National Strategic Development Plan”. It is important to determine whether water is safe to drink based on scientific test results. The values of the test results are compared to the standard values considered safe, and if the test results are within the standard values, the water can be considered safe. Water quality standard values are set based on the results of scientific verification. The WHO has published guideline values that are intended to be used as the basis for setting water quality standards in each country, and the NDWQS is set with reference to these guideline values and others.

For water quality test to determine whether tap water quality meets water quality standards, it is important to use test methods that are up to date and available in terms of technological standards, and the application of such reasonable methods will provide accurate, precise, and reliable results. In the "The data collection survey on water supply development in Phnom Penh capital in the Kingdom of Cambodia: final report. - (February 2022)" cited in section "1. Background and Purpose of the Study," the "9-3-2-2 Recommendations for the Year 2030" states that "the methods and systems for water quality monitoring should be reviewed," and as one of the policies, (1) Improve the accuracy and precision of analysis by adopting analytical methods specified in the NDWQS, and (2) Strengthen laboratories to be able to analyze all items specified in the NDWQS.

In this field survey, the following were confirmed in the water quality tests conducted by PPWSA.

1) Although absorbance spectrophotometers are used, calibration curves are not prepared on a case-by-case basis, and relatively simple analytical methods using pre-mixed and pre-packed analytical reagents are employed.
2) The above test methods do not allow independent control of the quality of the analysis, such as the accuracy of the test method.
3) The above testing methods do not allow for technical and flexible responses to changes in coexisting substances and their concentrations in the sample.
4) Some NDWQS items for which PPWSA does not have testing capabilities are outsourced to overseas analytical laboratories, and it takes more than one month to confirm the test results.
5) Therefore, there are concerns about whether emergency responses will be properly implemented.

In order for PPWSA to solve these issues, it is required to establish a water quality testing system that can be done independently. This will greatly improve the current situation where water quality test is outsourced to an overseas analysis laboratory by transferring analysis samples out of the country, and in addition to confirming test results extremely quickly, it will also enable PPWSA to respond to sudden abnormalities in water quality on its own. The PPWSA will be able to establish a much more secure system, not only for the PPWSA, but also for all water utilities in Cambodia, by allowing them to outsource their water quality test to the PPWSA. Furthermore, the future vision of the water quality laboratory at PPWSA includes a proposal to become the best laboratory in Cambodia in terms of water quality, and by establishing a leadership position and role in Cambodia, it is envisioned that the laboratory will play a leading role in the country's water supply business as a whole.

PPWSA is the largest authority in the country that supplies tap water to the capital city of Phnom Penh and other areas, and its large water supply volume and high water quality are attracting attention from all over the world. If such an authority were to develop its current water quality laboratory into a "water quality center" with even higher capabilities and take charge of water quality test not only for PPWSA but also for the entire country, it would further enhance the safety and reliability of the country's water supply and contribute greatly to improving the health of the people. This will also contribute greatly to the improvement of the health of the people of the country. The establishment of a “water quality center” in PPWSA is an urgent issue, and it is essential to start the process of establishing such a center.

3.2 Current Actual Status of Existing Facilities and Equipment in the Water Laboratory

The following is a description of the current status of the PPWSA water laboratory as confirmed by the field survey and the responses to the questionnaire sent to the PPWSA water laboratory prior to the field survey.

3.2.1 Current Status of PPWSA Water Laboratory

(1) Organization of PPWSA and Water Laboratory

The position of the water laboratory within the PPWSA organization is shown in ***Figure 3-1*** as a schematic diagram. The organization that effectively manages the waterworks is headed by the Director General, who in turn has seven Departments under the jurisdiction of Deputy Director Generals, each of which has several subordinate Offices. The Water Laboratory belongs to the Production System Department, together with the Production Office and the Mechanical and Electrical Office, which are in charge of the six water treatment plants.

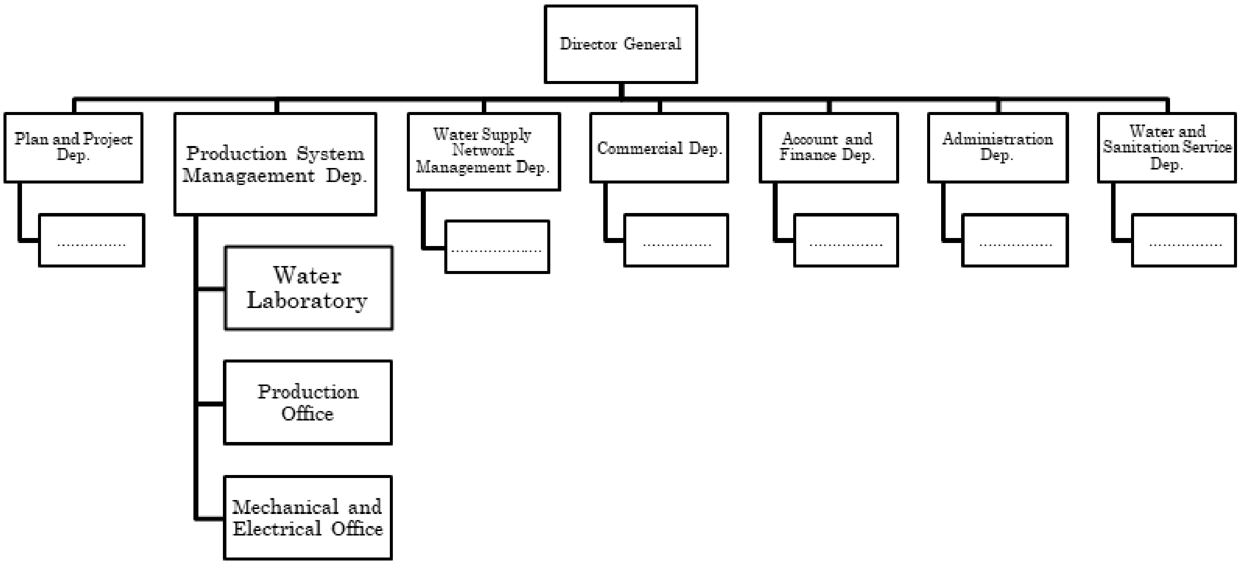

Figure 3-1 Schematic of PPWSA Organization and Water Laboratory
Source: JST

(2) Role of Water Laboratory in PPWSA

The PPWSA defines the role of the water laboratory as follows.

・To assure the quality of clean water supplied by all Water Treatment Plants with testing criteria parameters comply with CNDWQS and WHO Standard and assist to other waterworks in Cambodia in the field of water quality testing.

For the water laboratory to adequately fulfill this role, it is necessary to retain the ability to perform the following.

1. The water laboratory can accurately measure standard concentration levels for all NDWQS water quality items.
2. The water laboratory can accurately measure water quality items indicated in the WHO guidelines for drinking-water quality that are of concern in Cambodia.
3. As a leadership entity for domestic water utilities, the water laboratory will strive to accumulate further technology and knowledge and enhance a more advanced water quality management system in order to request water quality measurements from domestic water utilities in Cambodia and provide advice to water utilities planning to develop a water quality management system.

Furthermore, in order for "the tap water supplied from the water purification plant to always be normal," it is necessary to confirm that the water purification process is always in good working order. In addition to the above, the system must be able to respond quickly in the event of abnormalities such as chemical spills, abnormal algae growth, etc. at the water resource area and must maintain the following capabilities.

4. Monitor water quality on a daily basis at the water treatment plant and water supply area.
5. Ability to respond urgently in case of abnormalities in raw water and tap water quality.

For items 1~3 in the bulleted numbers above, the improvement of measurement capacity, focusing on the tangible aspects, will be required, and for items 3~5, the improvement of intangible capacity related to water quality management will be required.

(3) Budget for Water Laboratory

The budget of the water laboratory is shown for supplies directly required for water quality testing and for maintenance and purchase of measuring equipment. This budget does not include personnel costs for water quality laboratory staff or facility maintenance and operation costs.

1) Consumables cost budget such as glassware, reagents, etc.

Table 3-1 shows the budget of consumables cost such as glassware and reagents in 2023 and 2024. The budget of consumables costs in 2024 have almost doubled compared to 2023.

Table 3-1 Consumables Cost Budget Such as Glassware, Reagents, etc.

Fiscal year	Budgetary amount（USD）
2023	65,620
2024	116,875

Source: JST

2) Budget for maintenance and purchase of measuring and other equipment

Table 3-2 shows maintenance and purchase costs for measuring and other equipment from 2021 to 2024. In 2024, maintenance and equipment costs have increased significantly compared to the previous three years.

Table 3-2 Budget for Maintenance and Purchase of Measuring and Other Equipment

Fiscal year	Budgetary amount（USD）
2021	73,126
2022	63,426
2023	35,869
2024	150,060

Source: JST

(4) Action Plan for the Future of Water Laboratory and Current Challenges

1) Action plan for the future of water laboratory

Future action plans for the water laboratory include the following.

・Capacity building on water quality testing
・General Personnel Development programs provide employees with the knowledge of good management
・Attending seminars or conferences related with outside agencies with specific expertise to enhance their technical knowledge and experience knowledge and experience of staff
・When a new test or new project is developed, the training programs need to be more specific to the working group in order to develop their skills and knowledge in the subject

All of these items are considered indicate that water quality laboratories view the development of human resources and the acquisition of skills and knowledge in water quality testing, etc. as an urgent issue.

2) Current challenges for water laboratory

The water laboratory has identified the acquisition of the following analytical techniques as a current challenge.

1. Measurement of organic substances
2. Measurement of heavy metals
3. Measurement of pesticides

4. Quality analysis of poly aluminium chloride
5. Quality analysis of chlorine gas
6. Quality analysis of chlorine powder
7. Quality analysis of lime
8. Quality analysis of salt which is used as raw material of on-site chlorinator

All of these can be understood as a list of technical challenges that the water laboratory is, now facing at this time. To address these issues, several types of analytical instruments are necessary to address items 1 to 3. For 4~8, it is possible to analyze to confirm some quality items by using instruments owned by the water quality laboratory, however, analytical instruments (e.g., AAS) capable of measuring heavy metals are required for quality inspection of all items.

(5) Staff of Water Laboratory

The water quality laboratory has 13 full-time employees, and ***Table 3-3*** shows the categories of years of experience of these employees. In addition to full-time staff, several contract employees with less than one year of experience are assigned. Looking at the distribution of staff by years of experience, seven staff members have less than five years of experience, and the staff composition of the water quality laboratory is dominated by younger age groups. When introducing new analytical instruments as mentioned in "3.2.1(2) Role of water laboratory in PPWSA" and " 3.2.1(4) Action plan for the future of water laboratory and current challenges", one possible approach is to have pairs or groups of mid-career staff and younger staff receive training, education, and how to operate and maintain the instruments.

Table 3-3 Experience Years of Laboratory Staff

Years of experience	No. of staff
3 years ～ 5 years	4
5 years ～ 10 years	4
More than 10 years	5

Source: JST

(6) Human Resource Development (Training) Plan for Water Laboratory Staff

The types of training and the annual frequency provided to water quality laboratory staff are listed in ***Table 3-4***. Training based on ISO17025, which will be discussed later, and training for staff newly assigned to the water quality laboratory are each conducted once a year. Number of training sessions is not sufficient to maintain and develop a capacity of the water laboratory, and it is considered necessary to set up systematic water laboratory-wide training for the purpose of "Capacity building on water quality testing", as mentioned in "3.2.1(4) Action plan for the future of water laboratory and current challenges”. This includes the formulation of human resource development programs aimed at improving management knowledge for staff, participation in seminars and conferences held by external organizations on topics of expertise that may contribute to this, and participation in training programs to develop the skills and knowledge of work teams when new measurement methods are developed or projects are undertaken. Furthermore, as education and training methods that can be implemented within the organization, human resource development (training) can be made more effective by obtaining specialized books and creating an environment to hold study sessions for all water laboratory staff, and by actively participating in education and training programs and seminars related to water quality measurement held outside of Cambodia.

Table 3-4 Training for Water Laboratory Staff at Current

Types of training	Frequence
ISO17025 training	1/year
Training for new staff of water laboratory	1/year (Only at the time of hiring)

Source: JST

(7) Obtaining of External Agency Accreditation for ISO 17025

The water laboratory is accredited to the international standard (ISO 17025) developed by the International Organization for Standardization, which indicates that the laboratory has a competence of analysis. The accreditation is only for the Nirodh laboratory, while the water quality laboratories of the other four water treatment plants are exempt from accreditation. The five accredited measurement items are pH, electrical conductivity, turbidity, nitrite ion, and manganese ion. Nitrite and manganese ions are measured by reacting with commercially available reagents prepared in advance to produce a color, and the intensity of the color is measured using an absorbance spectrophotometer. This corresponds to the category of measurement methods commonly referred to as pack tests. The other items are measured using dedicated measuring instruments or dedicated electrodes, respectively.

ISO 17025 requires not only standard operating procedures (SOPs) describing measurement operations, but also that most of the inspection process, including the process of calculating concentrations, be recorded and stored so that it can be traced back to the correct implementation of measurement actions. Some record forms are also in place for this purpose. Internationally, it is understood to be a system that assures the outside world of the reliability and accuracy of water quality testing. If PPWSA introduces new analytical methods in the future, this system can be used to assure the reliability and accuracy of its own test results by maintaining its own documentation, even if it does not obtain new accreditation from an accreditation organization.

(8) Overview of Water Laboratories Located at Four Water Treatment Plants

1) Number of samples and items measured in each water laboratory

The four water treatment plants operated and managed by PPWSA are Phum Prek, Chroy Changvar, Chamcar Morn, and Nirodh. In addition to this, there is Bakhang water treatment plant, but it is managed by an organization other than PPWSA and could not be visited during this survey due to permitting procedures. In addition, no information such as water quality measurement results for the Bakhang water treatment plant was included in the responses to the preliminary questionnaire. Therefore, this section provides an overview of the water quality laboratories installed at the four water treatment plants, excluding the Bakheng water treatment plant. It should be noted that the Bakheng water treatment plant also has a water quality laboratory, which is staffed by PPWSA personnel.

The water quality laboratories located at each water purification plant measure the water quality and other parameters of each plant, and the results of turbidity, jar tests, and other items that serve as indicators of water purification treatment are reported to the water purification plants as soon as they are obtained and are used to control the operation of the plants. The number of samples of water quality items measured in each water quality laboratory is shown in ***Table 3-5*** for daily, weekly, and monthly measurements. The number of samples for the weekly and monthly measurements is 2 for all water treatment plants, and raw water and treated water are measured.

Table 3-5 Number of Samples of Each Water Laboratory

	Phum Prek	Chroy Changvar	Chamcar Morn	Nirodh
Daily measurements	18	18	12	18
Weekly measurements	2	2	2	2
Monthly measurements	2	2	2	2

Source: JST

Table 3-6 shows the number of water quality measurement items for each daily, weekly, and monthly measurements. In the daily and weekly measurments, the Chroy Changvar water treatment plant measured one more item than the other water treatment plants, because total dissolved solid (TDS) is measured in both raw and purified water. The number of samples for monthly measurments is the same for both raw water and drinking water at all water treatment plants. The number of items measured for purified water is two more than that for raw water, because free chlorine and residual chlorine are measured for purified water.

Table 3-6 Number of Measurement Items of Each Laboratory

		Phum Prek	Chroy Changvar	Chamcar Morn	Nirodh
Daily measurements	Raw water	8	9	8	8
	Purified water	10	11	10	10
Weekly measurements	Raw water	15	16	15	15
	Purified water	17	18	17	17
Monthly measurements	Raw water	37	37	37	37
	Purified water	39	39	39	39

Source: JST

Table 3-7 shows the number of full-time staff in each water laboratory. The Nirodh water treatment plant has the largest number of laboratory staff at 4. This is due to the fact that only the laboratory at the Nirodh water treatment plant conducts water quality measurements accredited under ISO 17025, and the laboratory is staffed by the chief of the water laboratory.

Table 3-7 Number of Staff at Each Laboratory

	Phum Prek	Chroy Changvar	Chamcar Morn	Nirodh	Bakheng
No. of staff	3	2	2	4	3

Source: JST

2) Main analytical instruments in each water laboratory

A list of the major water quality analytical instruments is shown in ***Table 3-8***. Since all laboratories analyze approximately the same items, the type and number of analytical instruments are almost same.

Table 3-8 Major Analytical Instruments in Each Laboratory

Turbidity meter	pH meter
Electric conductivity meter	UV/Visible absorption spectrophotometer
HACH absorption spectrophotometer	Residual chlorine meter
Electric constant temperature dryer	BOD Incubator
Water purifying apparatus	Electric balance
Draft chamber	Jar teste
Reagent refrigerator	Centrifuge
Incubator	Microscope

Source: JST

Photographs of the laboratories are shown below. Each of the laboratories is large enough, and in the Nirodh laboratory, a volumetric flask etc. which have calibrated according to ISO 17025 are identified. The entire laboratory was carefully cleaned and the laboratory environment is good. Instruments in the laboratory are arranged in an organized manner, and there are no instruments left unattended on the laboratory tables.

Chamcar Morn Inside the laboratory

Chamcar Morn Jar teste

Phum Prek Inside the laboratory

Phum Prek Water purifying apparatus

	
Nirodh Inside the laboratory	Nirodh Reagent refrigerator
	
Nirodh Chemical storage locker	Nirodh Volumetric flasks calibrated according to ISO 17025
	
Chroy Changvar Inside the laboratory	Chroy Changvar Measurement record files

Figure 3-2 Photographs of the Laboratories
Source: JST

(9) Water Quality Test for All Items Included in the NDWQS and Who Guideline Items
PPWSA outsources water quality testing of all items included in the NDWQS and WHO guideline items to a water quality laboratory outside of Cambodia once a year. In 2022, PPWSA commissioned TÜV SÜD PSB Pte. Ltd. in Singapore to test water samples collected from November 24 to 27 and obtained the test result for 117 items as of December 28 of the same year. The breakdown of analysis items is 1 microorganism (fecal coliform bacteria), 6 physicochemical items such as turbidity, and 73 pesticides and general organic matter items, of which about half are pesticides. There are 21 inorganic items and 16 metal and heavy metal items.

The laboratory of SÜD PSB Pte. Ltd. is accredited to ISO 17025, and the analytical instruments used for this measurement is shown in ***Table 3-9*** as a combination of analytical instruments and pretreatment for eliminating coexistence substances and extracting and concentrating the substances to be analyzed. The table also shows the types of items to be measured. The pretreatment methods used are: liquid extraction, solid phase extraction, purge trap or headspace method, and derivatization. The analytical instruments used are, ICP-MS, IC, GC-ECD and GC-MS.

Table 3-9 Measurement Methods in Commissioned Measurement

Items to be measured	Analytical methods and its pretreatment
Metals and Heavy metals	ICP-MS
Inorganic ions	IC
Chlorinated organic agricultural chemicals	GC-ECD
Chlorinated organics Haloacetic acids	Liquid-Liquid extraction-derivatization-GC-ECD
Volatile organic carbons	GC-MS （Capillary column method）
Organics	Solid phase extraction-GC-MS （Capillary column method）
Chlorinated disinfection by-products Chlorinated organic solvents Chlorinated organic agricultural chemicals, Dalapon	Liquid-Liquid extraction - GC-ECD
EDTA, NTA	Solid phase extraction-derivatization-GC-MS
Bromate	Derivatization-GC-MS（SIM method）
Items to be measured	Analytical methods and its pretreatment

Source: JST

3.3 Capability to Respond to Customer Needs and Emergency Situations

Water supply in urban areas is an extremely rational water supply system that can supply a sufficient amount of water to a large number of people. On the other hand, users have an almost exclusive supply and no other options for obtaining an abundance of water.

PPWSA has established a water supply system in Phnom Penh, the capital of its country, in a short period of time and continues to provide a world-class water supply. The safety of the water quality is also confirmed by conducting water quality tests in the supply area by itself. As a result, even if water users detect any abnormalities in the quality of the water they use, PPWSA has a certain ability to confirm whether or not there are any abnormalities, to investigate the causes of any abnormalities, and to correct the causes of any abnormalities. During this on-site survey, it was confirmed that there are 117 analytical items for which water quality tests are outsourced overseas, and that PPWSA does not have the water quality test capacity for many of these items. It is considered that when abnormalities in water quality are detected in raw water, etc., very quick testing of many water quality items is not possible. In the future, by working to understand the capacity to test for these items on its own, PPWSA will be able to further strengthen and establish its independence regarding water quality management, which will also lead to stronger user confidence in the quality of PPWSA's water supply. In order to respond appropriately in the event of water quality abnormalities, it is necessary to strengthen and develop water quality measurement capabilities more than ever before.

CHAPTER 4 SUCCESS CASE STUDIES

4.1 Examples of Developed Countries

4.1.1 Water Quality Management Systems in Japan

In Japan, water supply is basically managed by each local government, and water quality management is also carried out by water utilities established by each local government. It is extremely important to ensure that the quality of the water supply does not affect the health of the people who use it. To this end, it is essential to have a system to control water quality, facilities and personnel to carry out water quality control. The framework for water quality management is based on the Waterworks Law, and water utilities are responsible for setting up and staffing facilities. The Japan Water Works Association (JWWA), whose members include domestic water utilities, academic experts, and waterworks-related manufacturers, provides support to ensure that water quality management by water utilities is smoothly implemented in accordance with the established framework. In this part, outlines the contents of these activities.

(1) Water Quality Test System in Japan

The water quality control performed by each water utility is strictly implemented to meet the requirements set forth in the Water Supply Law (promulgated in 1957) and related laws and regulations established by the government, and the personnel who implement these requirements are the employees of each water utility. The Waterworks Law states that its purpose is to provide "clean, abundant, and inexpensive" water, and Article 4 sets water quality standards as requirements for clean water. Article 20 also stipulates that (1) water utilities must conduct water quality tests, (2) water quality test results must be recorded and preserved, and (3) inspection facilities must be established to conduct water quality tests. (It is also possible to outsource the tests to an inspection agency that has the necessary inspection capabilities.) The water quality standards set forth in Article 4 of the Water Supply Law currently stipulate standard values for 51 items. Those water quality standard items include 31 items related to human health, plus 20 items such as the appearance of tap water. Tap water must meet the standard values for 51 items included in the water quality standards, and if the standard values are exceeded, the water utility must take immediate action to ensure that the water quality meets all water quality standard values. It is also stated that some items may require immediate shutdown of the tap water supply.

Water utilities must test the quality of the water they supply to determine whether it meets water quality standards. This is stipulated in Article 20 of the aforementioned Waterworks Law, and is referred to as a "water quality test". On the other hand, water utilities measure treated water for proper treatment at water treatment plants, this measurement is called as “water quality measurement” or “water quality examination” and it is not considered as the “water quality test”. There is a distinction between “water quality measurements” and “water quality tests”, and the frequency and methods of the tests are defined in detail for each item in water quality tests. Methods of water quality testing are determined by the Mistry of Health, Labor and Welfare after confirming that test results are accurate and that the accuracy of testing is within a certain range[6]. Methods of water quality test determined by the Mistry include not only the instruments and chemicals used, but also the analytical instruments such as AAS and GC-MS used for tests are also specified for each item to be measured. Therefore, the testing facilities set up by water utilities to perform water quality test are equipped with multiple advanced analytical instruments.

The analytical instruments required for water quality test methods for water supply are listed in ***Table 4-1.*** In addition to basic water quality measuring instruments and equipment such as chemical balances, pH meters, and burettes, other advanced analytical instruments such as AS, AAS, FL-AAS, IC, ICP-MS, GC-MS, LC and LC-MS are necessary to conduct water quality test, Pre-treatment instruments that allow samples to be concentrated before injection into these instruments are also required for the water quality test.

[6] https://www.mhlw.go.jp/content/10900000/001077084.pdf

Table 4-1 Major Analytical Instruments Used in Water Quality Test (Japan)

Major analytical instruments used in water quality test	Items to be measured
Incubator	General bacteria, E. coli
Chemical balance	Total dissolved solid
pH meter with glass electrode	pH
AS	Nonionic surface active agent, Color, Turbidity
AAS	Hg
TOC meter	TOC
FL-AAS	Cd, Se, Pb, Cr^{6+}, Zn, Al, Fe, Cu, Na, Mn, Ca+Mg
IC	NO_2^-, NO_3^-, CN, F, B, Chlorate, Bromate, Na, Cl^-
ICP-Atomic Emission	Cd, Pb, Cr6+, Zn, Al, Fe, Cu, Na, Mn, Ca+Mg
ICP-MS	Cd, Se, Pb, Cr^{6+}, Zn, Al, Fe, Cu, Na, Mn, Ca+Mg
GC-MS	Chloroform, 1,4-dioxane, 1,2-Dichloroethylene, Dichloromethane, Tetrachloroethylene, Trichloroethylene, Benzene, Chloroacetic acid, Dichloroacetic acid, Dibromochloromethane, Total trihalomethanes, Trichloroacetic acid, Bromodichloromethane, Bromoform, Formaldehyde, Geosmin, 2-Methylisobolneol, Phenols
LC	Anionic surface active agent
LC/MS	Chloroacetic acid, Dichloroacetic acid, Trichloroacetic acid, Formaldehyde, Phenols

Source: JST

Thus, Japanese water utilities maintain sophisticated analytical equipment, the purpose of which is to meet the technical requirements for water quality tests set by the government to ensure a certain level of tap water safety. Many of the entities that have installed analytical equipment and facilities for water quality tests, as well as staffing for water quality tests, are also simultaneously researching the water quality issues of individual water utilities. On the other hand, the total annual cost of owning these analytical instruments is high, including the cost of to install or replace new equipment, as well as the cost of water quality measurement facilities, the cost of maintenance the analytical instruments, and the cost of securing and hiring analytical technicians. All of these costs are borne by individual water utilities and are understood to be necessary to ensure the safety of water quality. In addition, small water utilities that cannot bear the cost of "water quality test" equipment and facilities for financial reasons, outsource the measurement of "water quality test" to an analytical laboratory that maintains the aforementioned analytical instruments and facilities.

(2) Japan Water Works Association

The purpose of the Japan Water Works Association is to contribute to the promotion of public health by promoting waterworks and its sound development, and its members include waterworks utilities as well as waterworks-related companies[7]. The current organization was established in 1932, but the organization of the advancement of waterworks association was established earlier in 1904, The purpose of this organization was to study and research various issues related to the construction, sanitation, and management sectors of the water supply system.

As one of the activities at that time in 1904, the "Agreement on Waterworks Test" was prepared as a result of studying the unification of waterworks quality test methods. Since then, the title of the book has been changed to "Water Examination Methods" and it has been continuously revised. The Water Examination Methods is applied to process examinations of raw water and treated process water conducted by water utilities at water treatment plants and other facilities. Furthermore, it also conforms to the aforementioned inspection methods for water quality testing established by the government.

The revision of the drinking water testing method is being studied by a committee established within the Japan Water Works Association. In addition to experts from national and local agencies, the committee includes many engineers in charge of water quality control at water utilities. Newly developed test methods are examined for accuracy, precision, and operability by water quality laboratories at several water utilities, and the results of these examinations are discussed by the Committee, and if deemed appropriate, are

[7] http://www.jwwa.or.jp/

adopted as the method of the Water Examination Method. Because they have been reviewed by several utilyties beforehand, the new test methods have been implemented very smoothly in many water quality laboratories that control water quality. Multiple methods are indicated for a single water quality item in the drinking water examination methods, and as mentioned above, the water quality test methods established by the government are also included in the drinking water testing methods. Therefore, analytical equipment installed for water quality test can also be used for measurement of drinking water test methods, allowing for rational use of analytical equipment.

In 2004, the Japan Water Works Association established the "Code of Good Laboratory Practice for Water Quality Testing (Waterworks GLP)" to ensure that the results of water quality testing conducted by water utilities are accurate and of the necessary precision, as well as to guarantee the reliability of testing operations. The Code conforms to ISO 9001 as a quality management system and incorporates some of the requirements of ISO 17025, taking into account the actual conditions of water quality tests for waterworks. Waterworks GLP is a system that is voluntarily introduced by water supply laboratories and private inspection agencies that conduct water quality tests. This accreditation further assures the safety of tap water quality, allowing tap water users to use tap water with greater reassurance. To date, more than 150 laboratories and laboratories have been accredited for water supply GLP, and almost all laboratories and organizations have renewed their accreditation and are continuing the GLP.

As shown here, the Japan Water Works Association continues to publish and revise the "Water Examination Methods" so that standardized examination methods can be smoothly and easily incorporated into tap water quality examination, and also conducts waterworks GLP accreditation work to compensate for the accuracy and reliability of water quality examination results.

(3) Equipment required at water quality centers3),4) (example of Japan)

The role of the WQC in the water utility is to measurement water quality to ensure that there are no abnormalities in the water source, the treatment process at the water treatment plant, and the process of distributing water, and to test water quality to ensure that the water to be supplied meets water quality standards.

The WQC requires space for measurement operations and space to install measurement equipment, including electrical equipment, water supply and drainage equipment, and general ventilation equipment. Even in applications where general water quality items are measured, the space is appropriately divided so as not to be affected by gases and vapors exhausted by an operation of a measurement. When advanced analytical equipment is installed, piping facilities for high-pressure gas necessary for operating the analytical equipment and local exhaust ventilation facilities for exhausting the gas generated when the equipment is operated are provided. In addition, most of the WQC locations are air-conditioned to maintain the temperature and humidity under the specified conditions in terms of maintenance of the analytical instruments and ensuring measurement accuracy.

1) Chemical examination room

The size is generally considered to be 100 m^2 to 200 m^2, and a draft chamber is provided if necessary. In some places, piping for high-pressure gases such as nitrogen gas is provided when pre-processing equipment such as solid-phase extraction equipment is installed. Many places have a separate chemical balance room adjacent to the chemical examination room, where vibration and dust can be avoided.

2) Analytical instruments room

An analytical instruments room is a place where instruments such as AAS, ICP-MS, GC-MS, HPLC-MS, and IC are installed. 20 m^2 or more is the size of one room, and often several instruments are installed in the same room. When multiple instruments are installed, the type of instruments to be installed in the same room is often determined based on the type of exhaust gas generated and other factors, and local exhaust ventilation facilities are provided for each. When considering an analytical instruments room, it is advisable to take into account plans for future introduction of instruments, etc., and ensure that space and locations for local exhaust ventilation facilities are provided in line with future plans, as well as that there is sufficient room for power supply capacity.

Of the analytical instruments mentioned above, except for IC, other instruments require high-pressure gases such as nitrogen gas, acetylene gas, and argon gas for operation. It is better to set up a gas cylinder room separate from the analytical instruments room and install pipes for high-pressure gas from there to maintain safety against leakage of high-pressure gas. If high-pressure gas cylinders are to be brought into the analytical instruments room for use, the route for bringing them in must be secured.

3) Bacterial testing room
In many cases, a bacterial test preparation room for the preparation of culture media and a bacterial culture room for the examination of bacteria are provided separately. Each room is about 20 m2 or more in size, and is equipped with sterilizing lights, independent air conditioning, and exhaust equipment or ventilation fans as needed.

4) Biological testing room
Some facilities have separate rooms for preparation of samples for biological examination and for microscopy. Each room is about 20 m2 or more in size and is equipped with an exhaust system or a draft chamber as necessary.

In addition to the aforementioned compartments, the WQC is equipped with a chemical and instrument storage room, an office room, and other facilities to prevent theft and fire. ***Table 4-2*** and ***Table 4-3*** show the general equipment and instruments installed in the WQC.

Table 4-2 Analytical Instruments and Equipment of the WQC

Water sampling equipment	AS
Thermometer	Turbidimeter
Residual chlorine meter	DO Meter
Pure water production equipment	AAS
Balance	Mercury analyzer
Heater	ICP-AE
Shaker	ICP-MS
Electric constant-temperature dryer	IC
Distillation equipment	TOC meter
Vacuum pump	GC-MS
Electric furnace	LC
Refrigerator	LC-MS
Ultrapure water production equipment	Microscope
Centrifuges	High-pressure steam sterilizer
Solid-phase extraction equipment	Dry heat sterilizer
Conductivity meter	Thermostatic incubator
pH meter	

Source: JST

Table 4-3 Laboratory Facilities at the WQC

Draft chamber
Sink
Lab benches
Balance table
Clean bench
Instrument storage cupboard
Chemical storage cupboard
Floor sink
Air conditioning equipment
Ventilation fan
Experimental liquid waste treatment equipment
Electrical equipment
Gas facilities
Various high-pressure gas piping facilities

Source: JST

(4) Size of WQC and Layout of Main Facilities

The following is an overview of the facilities and equipment of WQC at Japanese water utilities[8][9], as summarized in "The Design Criteria for Water Supply Facilities 2012" and "Water Supply Facilities Maintenance Manual 2006" published by the Japan Water Works Association.

Water Supply Facilities Maintenance Manual 2006 summarizes the relationship between area of WQC and water utility size as shown in ***Table 4-4***. (The data shown here is not an aggregate of all Japanese entities.)

Table 4-4 Size of Water Utility and Area of WQC (example from Japan)

Utility Type	Authority Size (by population served)	Number of authorities	WQC area (average: m2)	Number of technical staff (average: persons)
Water supply authority (54 authorities)	More than 1,000,000 people	11	2488	38
	100,000～1,000,000 people	34	390	6
	Less than 100,000 people	9	110	3
Bulk water supply authority (40 authorities)	More than 1,000,000 people	9	1786	24
	100,000 people～1,000,000 people	24	327	6
	Less than 100,000 people	7	185	2.4

Source: JST

It can be seen that authorities with a water supply population of more than 1 million have WQC with a larger area of more than 1,000 m^2 compared to authorities with a smaller water supply population. These large water authorities measure not only for 51 water quality standards items, but also for items of setting water quality control target and more than 100 individual pesticides and herbicide that complement the water quality standards, as well as for other items, including whether they are present in the water source. Large-scale authorities conduct their own measurements to confirm the safety of tap water and promote the fact that tap water is safe to their customers who use it.

The area of WQC of medium-sized water authorities is 300~400 m2 on average. These WQCs measure water quality standard items and items of setting water quality control target and more than 100 individual pesticides and herbicide that complement the water quality standards. On the other hand, they do not investigate substances that are not specified in water quality standards, as large entities do, and often do not have the analytical equipment to do so. When it becomes necessary to investigate unknown substances, there are examples of joint investigations with large entities that taking raw water from the same water source. For authorities supplying less than 100,000 people, all water quality standard items are measured, as well as some of the items for which water quality control targets are set. All water quality testing facilities, regardless of the size of the authorities, test the quality of the tap water concerned when requested to do so by customers and communicate the test results.

Table 4-5 shows an overview of major equipment located in WQCs, and data for 100 m^2 and 600 m^2 area are compiled based on the description in the " The Design Criteria for Water Supply Facilities 2012". Draft chambers and clean benches are essential equipment even for WQCs that are smaller in size. In addition, it can be confirmed that a sufficient number of laboratory tables (including those with attached sinks) should be placed in WQCs.

Table 4-5 Number of Major Equipment in WQCs

Laboratory Equipment	WQC with an area of 100 m^2	WQC with an area of 600 m^2	Laboratory Equipment
Draft chamber	1	3	Draft chamber
Laboratory tables (including those with sinks)	12	16	Laboratory tables (including those with sinks)
Shelves for instruments and chemicals	4	18	Shelves for instruments and chemicals
Clean bench	1	1	Clean bench

Source: JST

[8] The Design Criteria for Water Supply Facilities 2012、Japan Water Works Association、2012
[9] Water Supply Facilities Maintenance Manual　2006、Japan Water Works Association、2006

4.1.2 WQC of Metropolitan Waterworks Authority I Thailand

The WQC of the Metropolitan Waterworks Authority (MWA) was surveyed. The survey was conducted by sending a questionnaire, obtaining responses prior to the survey, and visiting the center on January 19, 2024.

(1) Outlines of MWA

MWA[10] is a water utility that supplies water to Bangkok and the surrounding areas of Nonthaburi and Samut Prakan. Established in August 1967, the current water supply area covers a total area of approximately 2,500 km2, with a total of approximately 2.6 million cases of water supply and an annual water supply volume of approximately 1.34 billion m^3.

(2) Organization and Water Quality Department of MWA

An overview of MWA's organization for substantial water supply is shown in ***Figure 4-1***. Under the Governor, eight Deputy Governors are in charge of the departments of Administration, Finance, Engineering, Water Purification, Planning and Development, Digital Technology, Eastern Region Services, and Western Region Services, respectively. Under each Deputy Governor, there are one to four Assistant Governors, each of whom is responsible for the operations of two to four Departments or Offices. The organization in charge of water quality analysis is the Water Quality Analysis Division, which belongs to the Water Quality Department. The Water Quality Analysis Division belongs to the Water Quality Department, which is headed by the Assistant Governor in charge of Water Resources and Quality, and the Duputy Govrner in charge of Water Production, which oversees the three divisions, including the Water Resources and Quality Division.

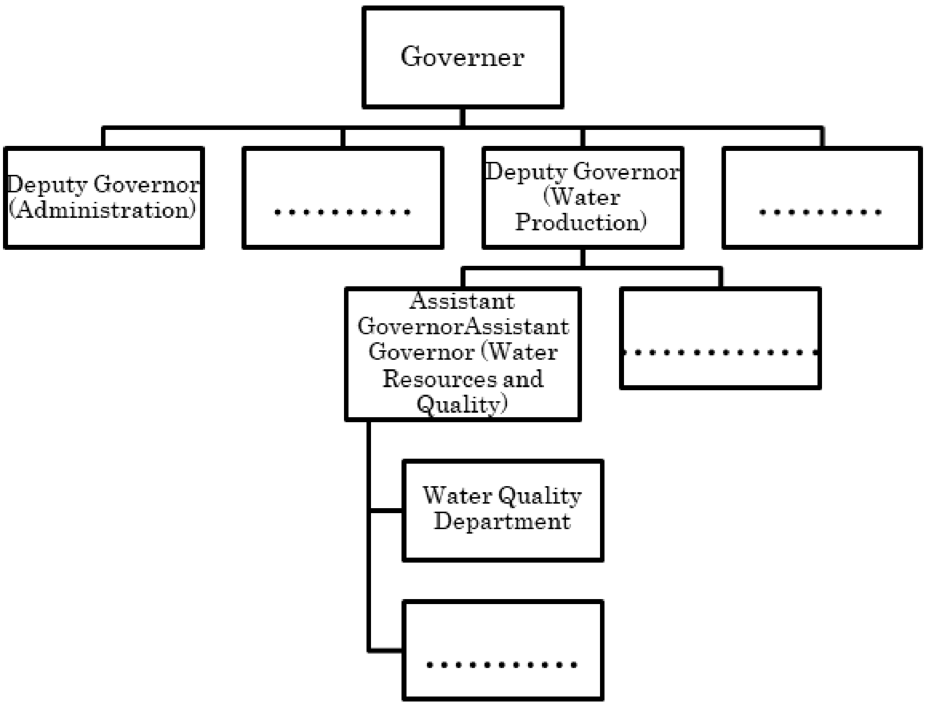

Figure 4-1 Organization of MWA and Water Quality Department
Source: JST

(3) WQC (Water Quality Department)

In the organization of MWA, the Water Quality Department is in charge of water quality analysis, and the actual analysis is performed by the Water Quality Analysis Division (WQA), which is located in the Water Quality Department. This part describes the history of the Water Quality Department, focusing on an overview of the division in charge of water quality analysis.

1) Organization of Water Quality Analysis Division

The organization of the Water Quality Department, including the Water Quality Analysis Division, is shown

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[10] Annual Report 2022、Metropolitan Waterworks Authority

in ***Figure 4-2***. The Water Quality Analysis Division includes the Chemical Analysis Section, the Microbiological Analysis Section, the Toxic Substance and Heavy Metal Analysis Section, and the Quality System Management Section. In addition to the Water Quality Analysis Division, the Water Quality Assessment Division and the Water Quality Integration Division have been established in the Water Quality Department.

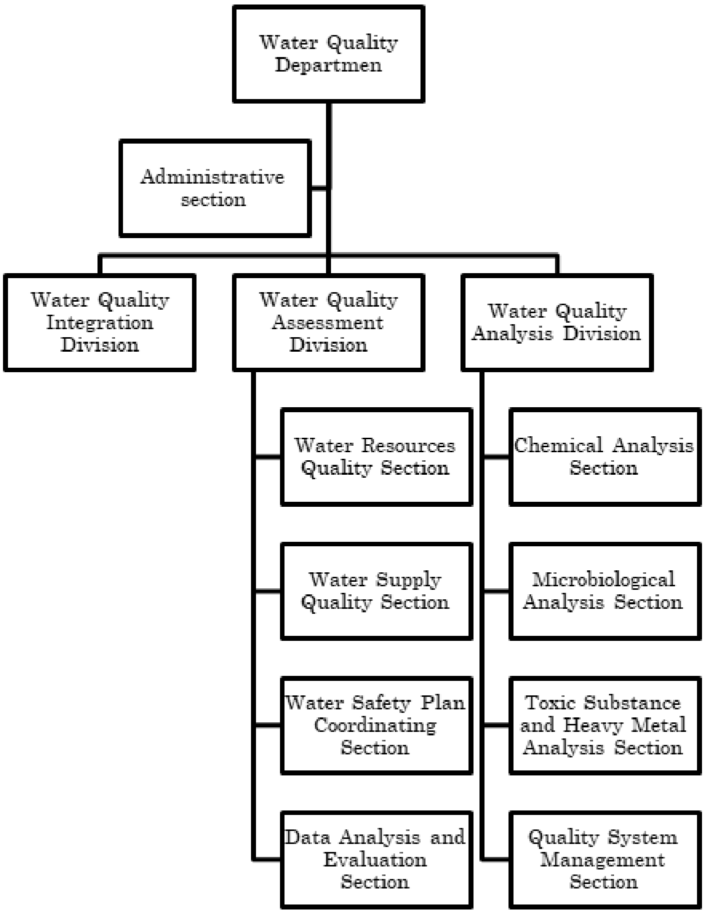


Figure 4-2 Organization of the Water Quality Department
Source: JST

2) History of the Water Quality Analysis Division

The previous organization of the Water Quality Analysis Division was established in 1914 with the start of operation of the first water treatment plant to supply water to the city of Bangkok. With the establishment of MWA, it became an organization of the Metropolitan Waterworks Authority of Thailand, and was promoted from "Unit" to "Section" in the original organization, and became the current "Division" in 1974. The name was later changed when the organization was reorganized, and the division was placed under the Water Quality Department along with other newly established divisions in charge of water quality. Today, three divisions and nine sections belong to the Water Quality Department.

In addition to the aforementioned Water Quality Analysis Division, the Water Quality Division is composed of the Water Quality Assessment Division, where this includes the Water Resources Quality Section, the Water Supply Quality Section, the Water Safety Plan Coordinating Section, the Data Analysis and Evaluation Section, and the Water Safety Plan Coordinating Section. These two sections are jointly responsible for water quality control from the water source to taps. The Water Quality Integration Division manages the water quality automatic measuring devices set up within MWA's water supply area and is responsible for monitoring water quality within the area and controlling additional chlorine dose rate in distribution ponds and other locations. Based on these facts and reality, it is assumed that the Water Quality Department plays the role of a "water quality center" for water utilities as it is generally recognized.

In October 2004, the department in charge of water quality analysis received Guide25 accreditation, which guarantees the accuracy and reliability of the results of chemical and water quality analysis. Today, Guide25 is ISO 17025.

3) Role of the Water Quality Analysis Division

MWA defines the role of the Water Quality Analysis Division as follows: In addition to testing the tap water supplied by MWA, the Water Quality Analysis Division is also responsible for contracting outside water quality testing. In addition, the intent to utilize ISO/IEC 17025 accreditation is recognized to ensure the accuracy of water quality testing results conducted by the Water Quality Analysis Division and the confidence of internal and external parties in the test results.

1. Manage and supervise water quality testing work in the laboratory including tools, materials, equipment, chemicals. As well as developing the ability of testers to be ready to provide water quality testing services to internal agencies according to their mission to deliver quality tap water and agencies outside the organization to generate income from related businesses.
2. Manage and provide testing services and prepare professional water quality test reports that covers test items required to certify water quality in accordance with relevant water quality standards. To confirm cleanliness and safety to raise the quality-of-life of the people.
3. Manage the quality system according to ISO/IEC 17025 requirements, including document control, receiving water samples, Laboratory information system, prepare test report and assessment to maintain the system.
4. Study, research, and develop modern water quality testing technology with accurate result according to international standards.
5. Provide advice, consultation, and disseminate knowledge and understanding of scientific subjects related to water quality testing through various communication channels.

4) Policies of the Water Quality Analysis Division

MWA has established the following policy for its Water Quality Analysis Division.

・Committed to developing water quality testing according to international standard with transparency, impartiality, and professional quality consistent.

5) Budgets of the Water Quality Analysis Division

In FY2023/2024, the cost of consumables such as glassware and reagents amounted to USD 92,000. Table 15 shows the changes in the cost of purchasing expensive equipment such as analytical instruments (fixed asset costs) over the past five years and the main equipment purchased in each year. The budgeted amount for FY2020/2021 is USD 677,720, which is up to 10 times higher than in other years. This is likely due to the purchase of extremely expensive analytical equipment such as GC-MS, LC, and ICP-MS.

Table 4-6 Cost of Purchasing Analytical Instruments and Other Equipment

Fiscal Year	Budgets （USD）	Major instruments purchased
2019/2020	74,660	LIMS, etc.
2020/2021	677,720	GC-MS, HPLC, ICP-MS, etc.
2021/2022	52,200	
2022/2023	21,000	
2023/2014	8,200	

Source: JST

6) Overview of personnel and analytical instruments in the Water Quality Analysis Division

The area of the Water Quality Analysis Division for water quality measurement work is 845 m^2, and the area of the section for clerical work is 227 m^2. The Water Quality Analysis Division has a total of 24 employees, including one division head, four section managers, 12 inspectors who conduct water quality measurements, six assistants who assist in water quality measurements, and one clerical staff member.

he main types and number of analytical instruments owned are shown in ***Table 4-7***. The Water Quality Analysis Division is equipped with all analytical instruments (AAS, ICP-MS, GC-MS, and HPLC) for measuring heavy metals and trace organics, as well as a mercury analyzer and a total organic carbon meter. The division also possesses a plate reader for ELISA (Method using antigen-antibody reaction: enzyme-linked immunosorbent assay), which can measure algal toxins such as microcystin, whose presence in raw water is sometimes a concern.

Table 4-7 Main Analytical Instruments

Main analytical instruments	No.
Absorption Spectrophotometer (AS)	5
Atomic Absorption Spectrometer (AAS)	2
Inductively Coupled Plasma Mass Spectrometer (ICP-MS)	1
Total Organic Carbon Analyzer (TOC)	1
Gas Chromatograph Mass Spectrometer (GC-MS)	2
High-performance Liquid Chromatograph (HPLC)	1
Other analytical instruments	
Turbidimeter	3
pH / Conductivity meter	6
Microscope	4
Mercury Analyzer	1
Analytical Balance	7
ELISA Plate Reader	1

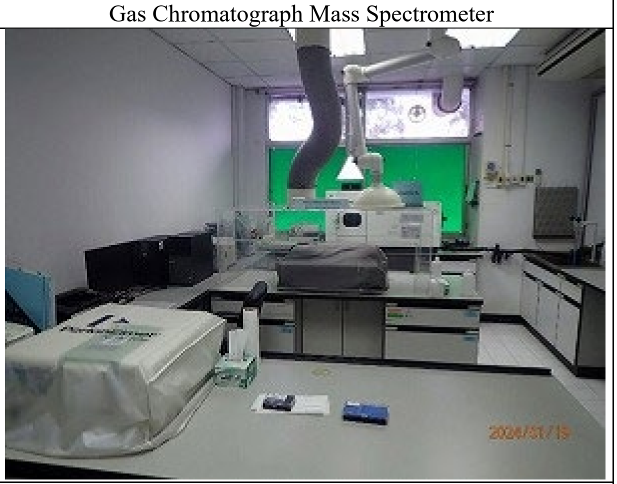
Source: JST

The following are pictures of the laboratory and analytical equipment of the Water Quality Analysis Division.

Compartmentalized Room

Gas Chromatograph Mass Spectrometer

Mercury Meter



Atomic Absorption Spectrometer

	
Laboratory view	Controlled waste liquid

7) Installation history of major analytical instruments

Figure 4-3 shows the history of major analytical instruments installed since the 1990's. In the 1990's, GC-ECD and AAS were installed. GC-ECD can measure trihalomethane (THM), a byproduct of chlorine disinfection. In the 2000s, HPLC (LC) was introduced to analyze agricultural chemicals like pesticides, and since the 2010s, the company has been introducing the latest analytical equipment and replacing previously introduced analytical instruments, and the costs required for this are estimated to have grown significantly compared to the costs spent previously. As for the latest analytical instruments, it is understood that ICP-OES (Inductively coupled plasma optical emission spectrometry), GC-MS, plate reader for ELISA method, ICP-MS, were installed, and instruments for measuring mercury, TOC, AS, etc. were replaced. Thus, in recent years, water quality measurement requires the development of multiple analytical instruments capable of measuring a wide variety of trace substances due to concerns about contamination by a wide variety of natural and synthetic substances. It can be inferred that MWA has continued to maintain state-of-the-art analytical equipment in recent years to address these substances and to ensure the safety of tap water.

GC-ECD for THMs; (discharge in 2022)	1992		
AAS brand G.B.G; (discharge in 2021)	1993		
		1999	New Building as present; UV/VIS Spectrophotometer, Lambda 20; (discharge in 2019)
HPLC for Carbamate; (discharge in 2023)	2001		
		2004	Accredited for Guide 25
Frame AAS and Graphite AAS;	2011		
		2012	ICP-OES; (discharge in 2023)
		2013	UV/VIS Spectrophotometer, Lambda35;
GC/MS;	2014		
Mercury Analyzer;	2017	2017	UV/VIS Spectrophotometer, Lambda365;
TOC Analyzer; ELISA Reader for algal toxin;	2019	2019	VIS Spectrophotometer;
GC/MS for THMs;	2022		
HPLC for Carbamate;	2023	2023	ICP-MS;

Figure 4-3 Installation History of Major Analytical Instruments
Source: JST

8) Number of samples to be measured by Water Quality Analysis Division

The annual number of samples measured by the Water Quality Analysis Division is shown in ***Table 4-8***. In addition to testing raw water, water in the treatment process, purified water, wastewater, and environmental water related to water treatment, the Water Quality Analysis Division also conducts quality tests for water treatment chemicals, leaching tests (testing of chemical substances that leach from materials and equipment into the water they come in contact with) and water quality tests contracted by outside organizations.

Table 4-8 Number of Samples per Year

Samples	Number of samples per year	Remarks
Water (raw, treated, drinking, waste, environment)	8,500	
Chemicals for water treatment	200	10% Sodium hypochlorite for disinfection
Extraction (Soluble chemicals) test for materials, equipment and sludge produced at water treatment plant	25	pipes, sand filter, water reservoir
External Contracted Samples	800	

Source: JST

9) Water Quality Items Being Measured

The items measured by the Water Quality Analysis Division are shown in ***Table 4-9***, divided into Sections: the Chemical Analysis Section measures 36 items, the Toxic Substance and Heavy Metal Analysis Section 46 items, and the Microbiological Analysis Section 19 items, for a total of 103 items measured.

Table 4-9 Items To Be Analyzed by Water Quality Analysis Division

Chemical Analysis Section （36 items）		
Appearance	Odor	Taste
Apparent color	True color	Turbidity
Conductivity	Salinity	pH
Temperature	Total solid	Total suspended solid
Total dissolved solid	Total alkalinity	P-alkalinity
Total harness	Carbonate hardness	Non-carbonate hardness
Calcium	Magnesium	Sulphate ion
Chloride	Fluoride	Iron
Manganese	Silicon	Sodium
Potassium	Cyanide	Total nitrogen
Total phosphorus	Total residual chlorine	Available chlorine
Specific Gravity (NaOCl)	Free chlorine	
Toxic Substance and Heavy Metal Analysis Section（46 items）		
Cupper	Zinc	Lead
Total chromium	Cadmium	Arsenic
Mercury	Nickel	Silver
Aluminum	Antimony	Barium
Selenium	Benzene	Toluene
Chlorobenzene	m-Xylene	Styrene
Iso-propylbenzene	n- propylbenzene	1,3,5-trimethlbenzene
Tert-butylbenzene	1,1,1-trichloroethane	Trichloroethene
Tetrachloroethene	Vinyl chloride	Transe-1,2-dichloroethene
Cis-1,2-dichloroethene	Carbon tetrachloride	1,2-dichloroethane
Ethylbenzene	Total organic carbon	Chloroform
Bromodichloromethane	Dibromochloromethane	Bromoform
Aldicarb sulfoxide	Aldicarb	Aldicarb sulfone
Oxamyl	Methamyl	Methiocarb
3-Hydroxy-carbofuran	Propoxur	Carbofuran
Carbaryl	Microcystin	Cylindrospermopsin
Microbiological Analysis Section（19 items）		
Ammonia Nitrogen	Nitrate	Nitrite
Dissolved Oxygen	Biological oxygen demand	Oxygen consumed
Heterotrophic bacteria	Total coliform bacteria	Fecal coliform bacteria
E. coli	Clostridium	Pseudomonas aeruginosa
Salmonella spp.	Shigella sp.	Staphylococcus aureus
Vibrio cholera	Bacillus oereus	Swab test (for HPC, E.coli, etc.)
Algae		

Source: JST

10) Obtaining GLP (Good Laboratory Practice) accreditation and quality control quality assurance of measurement

Water Quality Analysis Division is accredited or certified for the following two GLPs.

・ISO 17025
・ESPReL (Enhancement of Safety Practice in Research Laboratory in Thailand)

As mentioned above, ISO 17025 was developed by the International Organization for Standardization and is used as a standard for accrediting the competence of laboratories. Test results issued by laboratories accredited to ISO 17025 are highly regarded for their reliability as internationally accepted certificates.MWA's Water Quality Analysis Division has gotten accreditation of ISO 17025 in 2004 (then known as Guide25). and ESPReL accreditation in 2022. The ISO 17025 accredited analysis items are turbidity, iron, copper, coliforms, and E. coli. In the future, the division will consider changing the accredited analysis method for metals. One of the advantages of being accredited is that the accuracy of the test results can be trusted. As for ESPReL, they also cite that it ensures human and environmental safety in laboratory operations.

Control of analytical accuracy (QA/QC; Quality Control/Quality Assurance) and analytical proficiency testing of laboratory personnel are conducted in accordance with U.S. standard methods.

11) Issues and future plans for Water Quality Analysis Division

The following issues are noted as challenges for the Water Quality Analysis Division.

・Technology is diverse. We must choose the one that is appropriate for our job.
・Higher & complex technology needs more competency staff.
・Tools become obsolete when you have a budget.
・New parameters for quality testing need new equipment but it is costly to set up and may not worth the investment.
・Almost impossible to reallocate staffs within WQ Department, although the laboratory works is its main role because it is hard meticulous and fussy.

Future plans include consideration of initiating testing for haloacetic acids (HAAs), chlorine disinfection byproduct, as well as other disinfection byproducts. In addition, improvements to laboratory infrastructure facilities are being considered.

4.2 Factors to Strengthen and Establish Water Quality Testing Systems and Testing Facilities in Water Supply

The factors to strengthen and establish a water quality testing system are summarized with examples from Japan and a history of the expansion of the Water Quality Analysis Division at MWA, Thailand. There are at least 140 water quality testing centers in Japan, most of which have installed the advanced analytical equipment necessary for water quality testing. These water quality centers maintain the ability to accurately and precisely measure the 51 items indicated in the water quality standards. In addition to water quality standard items, the larger water quality centers measure raw water and etc. for trace chemicals and many types of pesticides whose health effects cannot be ruled out. These results are shared with other utilities as well. The following factors have contributed to the establishment and continued operation of a number of water quality centers in Japan with high laboratory capacity.

1. The water quality standards are set in the Waterworks Law and water utilities are required to conduct water quality testing.
2. The Waterworks Law requires water utilities to install water quality testing facilities with advanced analytical equipment and testing capabilities.
3. The Waterworks Law stipulates that a person in charge of water quality management, including water quality tests, must be appointed, and that there are provisions for supervision by administrative agencies and penalties.
4.Many water utilities participate in the committee established by the Japan Water Works Association to research and study water quality examination methods suitable for the current situation in Japan, and to disseminate knowledge and techniques for water quality examination by establishing and publishing the "Water Examination Methods".
5. The Japan Water Works Association has established the "Good Laboratory Practices for Water Quality Testing (Waterworks GLP)" and has built a system to enhance the accuracy and reliability of water quality test results conducted at each water quality center.
6. Water users drink tap water from their taps and pay a great deal of attention to the results of tap water

quality tests. Water utilities are making efforts to improve their water quality centers and testing facilities to meet the high level of interest of water users, and have the necessary budget and personnel with the necessary capabilities for testing.

In Japan, multiple factors described above complement each other to effectively manage tap water quality. Of the above, a major factor is that the law stipulates the development of facilities for water quality testing and the obligation to conduct such testing. This is a major reason why water utilities allocate large amounts of budget for water quality test and measurement.

4.3 Need to Develop a Roadmap of WQC Based on Request for Assistance from JICA

PPWSA was established in 1997 as a public corporation to supply water to the capital city of Phnom Penh and to maintain water supply facilities. The capital city of Phnom Penh is continuously supplied with water 24 hours a day, and as of 2019, the total water supply capacity is 590,000 m3 per day, with water treatment at five water treatment plants. The water laboratories located at the five water treatment plants analyze water quality to confirm CNWQS and to manage the operation of the plants. A total of 13 chemical staff members are assigned to the water laboratories at each water treatment plant. The water laboratories measure water quality on a daily basis, and the results are compiled and submitted to the Production System Management Department as monthly and annual reports.

One of the current issues in the water laboratory is that it does not measure 5 of the 26 items specified in the NDWQS and does not have analytical instruments to measure the 4 heavy metal items. The development of a measurement system for the NDWQS is an urgent issue for the PPWSA. The establishment of the NDWQS measurement system by PPWSA, which is the largest organization in Cambodia and has technical capabilities in water quality measurement, will make it possible for water utilities in Cambodia to request measurement, and will provide many water utilities and their users with a sense of security and confidence.

The development of the measurement system in the water laboratory of PPWSA can be divided into two major categories. One is the introduction of analytical instruments that can accurately and precisely measure lower concentrations of substances and measure many items (elements) at once. The other is the introduction of instruments that can measure substances other than the 26 items indicated in the NDWQS. Examples of the former include the AAS, which can measure low concentrations more accurately than absorption spectrophotometric analysis, and ICP-MS, which can measure multiple items (elements) simultaneously. An example of the latter is LC-MS. Both analytical instruments are considered necessary for rigorous and reliable water quality testing of water supplies, but no examples of their utilization were found in Cambodia except AAS.

These analyzers are precision instruments and must be operated carefully and without error. They also require specialized knowledge and skills for maintenance and upkeep, and are expensive. In addition, each instrument requires its own space for installation and its own equipment, such as local, on-site exhaust ventilation. Therefore, when these devices are introduced and operated, it is necessary to consider and maintain the following items.

1. Understand the conditions, environment, etc. required for each instrument and prepare a place to install it (environment includes prevention of contamination of samples from outside with regard to the element to be measured).
2. Learn how to operate each introduced instrument individually.
3. Establish an individualized maintenance, management, and upkeep system for each introduced instrument.
4.Depending on the equipment to be installed and the items to be measured, pre-treatment equipment that matches the characteristics of that instrument may be required.

Therefore, when PPWSA water laboratories introduce these instruments, the order in which they are introduced should be determined, taking into consideration the priority and importance of the items to be measured by the instruments, as well as the operability of the instruments. The necessary items for operation, such as training and education at the time of introduction, should be organized in chronological order. From the results of these studies, an overall picture of the laboratory where analytical instruments will be installed can be clarified. In other words, in the case of improving the current water quality measurement system, a roadmap for the development of water quality measurement facilities and the introduction of measurement equipment adapted to the national and PPWSA conditions in Cambodia is essential. The creation of a roadmap will ensure that the measurement system is quickly put in place and eliminate the "rework" that is expected to occur in the absence of such a system.

The development of a roadmap will provide information on advanced analytical instruments used for water quality testing. In developing a roadmap, examples from Japanese water utilities, which have many examples of water quality testing systems that utilize multiple advanced analytical instruments, will be of great help. The PPWSA requested JICA to assist in the preparation of a roadmap for strengthening and enhancing the water quality testing system, as the development of a water quality measurement system is an urgent matter, and Japan is well suited to respond to this request.

CHAPTER 5 DEVELOPMENT OF ROADMAP

5.1 Study of Water Quality Management System

5.1.1 Types and Roles of Water Quality Measurements

In Japa

The purpose of water quality measurement in waterworks can be broadly divided into the following two types, each with different objectives. The first is to confirm if there are any abnormalities in raw water, water in the treatment process at water treatment plants, tap water, etc. At the same time, the measurement results of raw water and water in the treatment process at water treatment plants are immediately used for optimization of water treatment process. The other is to confirm that tap water is safe for humans and that its quality does not impair the convenience of daily life. Here, the former is indicated as water quality tests and the latter as water quality examinations.

Table 5-1 provides an overview of water quality testing and water quality examination. It is important to fully understand the meaning and significance of both water quality measurements in order to control water quality. Examples of each type of measurement are also shown in the table.

Table 5-1 Types of Water Quality Measurements

Water Quality Examination
Daily and Weekly Water Quality Measurement (PPWSA)
Appropriate operation of water treatment **To check whether water treatment is normal and appropriate or not**
・Turbidity and Color etc. for PAC dosing rate control ・pH and Alkalinity for Lime dosing control ・Residual chlorine for Chlorine dosing control ・UV absorption and Dissolved Oxygen etc. for check of condition whether raw water is normal or abnormal
Water Quality Test
Monthly Water Quality Measurement (PPWSA)
Confirmation whether supplied water is safe and not to obstacle for ordinally use for consumers or not
・Arsenic, Cadmium for human health ・Iron and Manganese etc. for water for daily use

Source: JST

The characteristic differences between quality tests and water quality examinations are shown in ***Table 5-2***. They differ in contrast in terms of rapidity, accuracy, and precision in measurement. This is due to the difference in purpose, and it is important to fully understand the meaning and significance of both types of water quality measurements in managing water quality.

Table 5-2 Features of Water Quality Examination and Water Quality Testing

·Water Quality Examinations (Daily and Weekly Water Quality Measurement) ·Speedy and Frequent Measurement ·Effective and appropriate use of measurement results for water treatment ·Accuracy and Correctness aren’t essential ·Water Quality Test (Monthly Water Quality Measurement) ·Accurate and Correct Measurement ·Measurement speediness isn’t essential ·Disclosure of test results to consumers

Source: JST

The concept of items to be measured in water quality examination and water quality tests is shown in ***Table 5-3***. In water quality examination, water quality items to be used as reference in the operation and control of water treatment process and items that can determine whether there are abnormalities in raw water, etc. are to be selected. In water quality tests, items specified in water quality standards are measured, as well as selected items included in international guidelines, etc.

Table 5-3 Measurement Items of Water Quality Examinations and Water Quality Tests

·Water Quality Examinations (Daily and Weekly Water Quality Measurement) ·Parameters affecting the treatment process ·Parameters to determine if there is an abnormality in raw water ·Parameters to determine that there are no abnormalities in the treated water Color, Conductivity, pH, Turbidity, UV absorption, Free Available Chlorine, Alkalinity, etc. ·Water Quality Test (Monthly Water Quality Measurement) ·Parameters affecting human health (Water Quality Standard) ·Parameters affecting daily use of human living (Water Quality Standard) ·Parameters suspected to be present in tap water and of health concern (WHO Guideline, PPWSA's own parameters of concern) Arsenic, Cyanide, Fluoride, Pesticide, Algal toxins, etc.

Source: JST

In water quality examinations and water quality tests, ***Table 5-4*** shows the concept regarding measurement methods. In addition to methods that can achieve the objectives of water quality examinations, there are also cases in which the measurement methods are methods of their own devising, etc. On the other hand, in water quality tests, the basic rule is to use the methods specified in water quality standards, etc. If this is not possible due to unavailability of measuring instruments, reagents, etc., the next best response is to use internationally recognized measuring methods. The quality inspection of chemicals for water purification treatment will use a method determined by an organization such as a waterworks association, based on studies by experts and academics.

Table 5-4 Measurement Methods for Water Quality Examinations, Water Quality Tests and Quality Tests of Water Treatment Chemicals

·Water Quality Examinations (Daily and Weekly Water Quality Measurement) ·Any method that can achieve an objective ·Method developed by their own ·Water Quality Test (Monthly Water Quality Measurement) ·Methods whose accuracy and precision have been internationally confirmed ·Methods officially established by national governments, international organizations, etc. ·Material Quality Test ·Methods established by generally recognized organizations, institutions, etc., after consideration of experts, academics, etc. ·Pre-treatment method is completely different from water quality test

Source: JST

5.1.2 System of Water Quality Examinations and Water Quality Tests in PPWSA

PPWSA has a water laboratory at each of its water treatment plants, as shown in ***Figure 5-1***. Each water quality laboratory conducts approximately similar daily and weekly tests, as well as monthly tests that are equivalent to water quality tests. If a new WQC were to be established, there are two possible arrangements for the WQC and the current five laboratories, as shown in Figure. ***Figure 5-1*** shows the establishment of a WQC separate from the current laboratories, and the WQC would be responsible for conducting water quality tests and overseeing water quality management in the entire PPWSA. This water quality control could include a summary of water quality measurement techniques for the laboratories located in the water treatment plants.

The other arrangement, as shown in ***Figure 5-1***., is to place the WQC inside the water treatment plant and have the WQC take on the role of a laboratory at the water treatment plant. In this case, the water quality measurement equipment, etc. owned by the laboratory can be shared with the newly established WQC, and staff can be involved in the daily water quality management of the water treatment plant, etc. and in the water quality testing work conducted by the WQC, making the operation more rational. ***Figure 5-1*** shows an example of a water laboratory located at water treatment plant A together with the WQC.

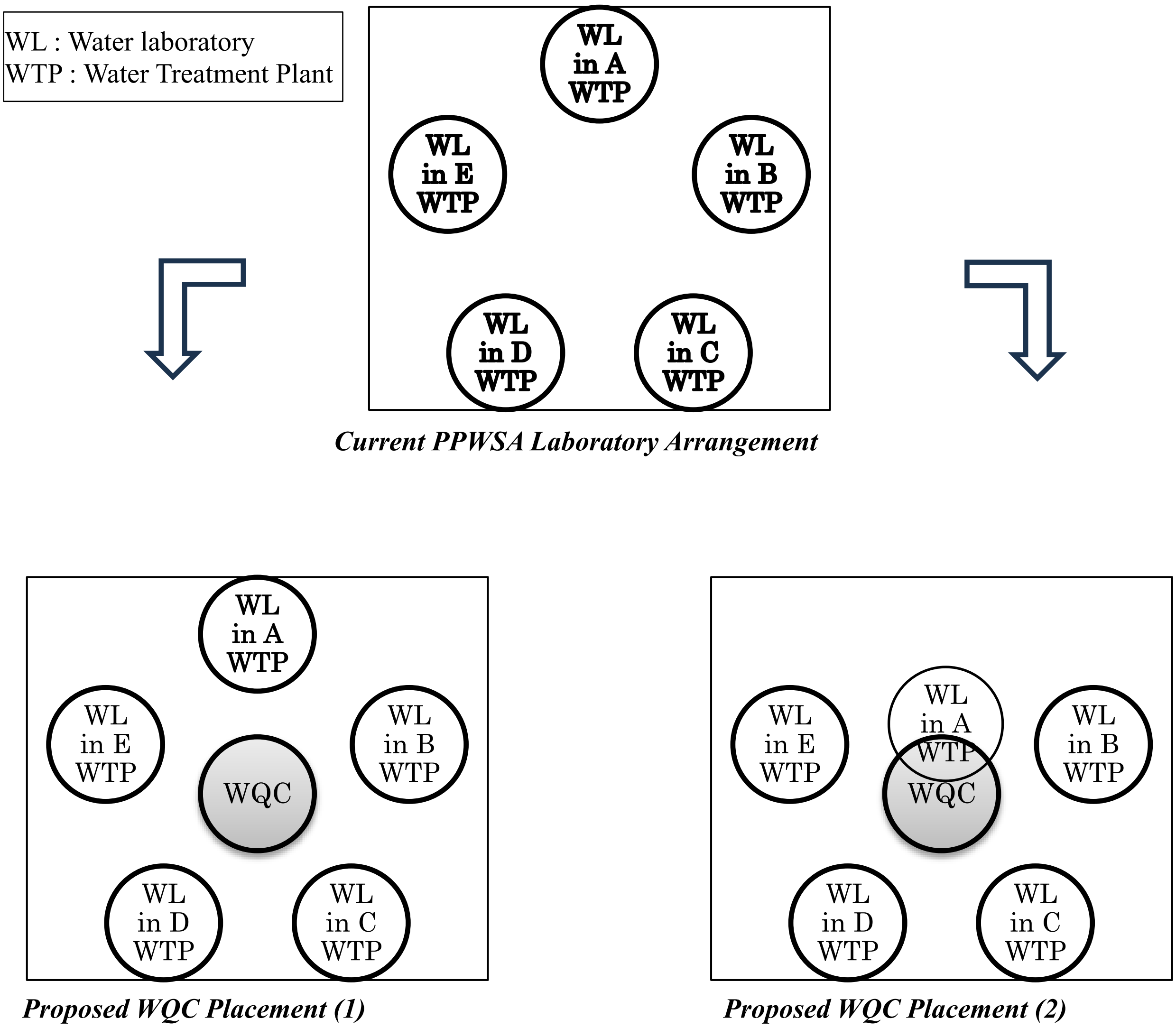


Figure 5-1 ***Proposed WQC Placement***
Source: JST

5.2 Basic Policies for Roadmap Development

The following are the basic policies in developing the roadmap for the establishment of the WQC.

1. It is essential that PPWSA's water quality management system is consistent with the NDWQS and the roadmap will be developed based on the contents of the NDWQS.
2. NDWQS article 59 states review for "Emerging Water Quality Issues" and "Testing methods ". At the time of revision of NDWQS, new water quality parameters and stricter conditions of test method may incorporate. The roadmap includes to counteract to new water quality items and measurement methods for the future.
3. Article 25 states that "The guideline values in current version of WHO's Water Guidelines shall be used for permissible limits." The roadmap includes measures to address water quality issues related to pesticides in the future.
4. Article 26 states that "The guideline maximum values in current editions of WHO's Water Guidelines shall be used for allowable limits for algal toxins." The roadmap includes measures to address water quality issues related to algae-produced toxins in the future.
5. It is important to contribute to the water supply in Cambodia. While confirming the intentions of the national regulatory agency and other water utilities, PPWSA create an organization that is able to undertake water quality test from other authority in the future.

5.3 Priority of Major Analysis Items

Based on "5.2 Basic policies for roadmap development," new chemical items to be analyzed will be determined in the order of the following items. Note that the advanced analytical instruments used in WQCs in developed countries require the latest technology, knowledge, and experience for operation, maintenance, and upkeep. It is natural that these instruments will be more complex to operate, and the analytical instruments initially introduced to PPWSA will be more complex to operate than the instruments currently in use. Therefore, with regard to the order in which the instruments are introduced, consideration is also given to the fact that the experience gained in dealing with the analytical instruments initially introduced to PPWSA will be as suitable as possible for training in the operation and maintenance of the analytical instruments to be introduced later, through the experience with the analytical instruments initially introduced. The relationship between newly introduced analytical instruments and analytical items is extremely strong and it influences the determination of the order from (2) onward, excluding (1), of the order shown below.

(1) All 26 parameters included in NDWQS can be measured by PPWSA.
(2) Measurements can be made with the same lower quantitation limits, accuracy, and precision as the measurement method approved by Article 36 of NDWQS.
(3) Inorganic ions, such as Nitrate and so on which they are included in NDWQS, can be measured by a simultaneous analysis method. Simultaneous analysis method is a method to measure multiple items at the same time
(4) Pesticides and herbicide used in relatively large quantities in Cambodia can be analyzed by a simultaneous analysis method.
(5) Metal ions, such as Aluminium and so on which they are included in NDWQS, can be measured by a simultaneous analysis method.
(6)Newly emerging substances which international organizations such as the WHO have raised concerns about being contained in tap water can be measured.

5.4 New Analytical Instruments to be Introduced and the Order in which they will be Introduced

Based on the major "5.3 Priority of major analysis items" described above, the instruments that need to be newly introduced and the items to be analyzed for each such instrument are listed below. As a result, the order is almost the same as the history of development of individual analytical instruments in the world, and also almost consistent with the history of instrument introduction by analytical institutions in developed countries. The types of analytical equipment to be introduced are selected as follows based on items (1) to (6) shown in "5.3 Priority of major analytical items".

5.4.1 Measurement of 26 Items as indicated in the NDWQS

(1) Measurement of 26 parameters included in NDWQS		
	New analytical instruments to be introduced	**Items to be newly analyzed**
	Atomic absorption spectrophotometer (AAS)	Barium (Ba), Cadmium (Cd), Sodium (Na)
	Flameless atomic absorption spectrophotometer (FL-AAS)	Arsenic (As)
	Cold vapor-Atomic absorption spectrophotometer (Cold vapor-AAS ; Hg meter)	Mercury (Hg)

AAS is simpler to use than FL-AAS, and routine water quality testing can be performed more quickly by installing both analyzers, so there are many cases where two instruments are installed at the same time. If one of the two instruments is to be introduced first, FL-AAS is recommended because it also has the function of AAS. The NDWQS requires water utilities using groundwater sources to test for arsenic; all PPWSA water sources are surface water, and arsenic is not an item subject to water quality testing by the PPWSA. However, PPWSA is the largest water utility in Cambodia and has a role to play in further promoting and advancing water services in the country. In Cambodia, there are many entities and cases where groundwater is extracted for tap water, and arsenic contamination of drinking water is a major problem in neighboring countries; PPWSA's arsenic testing capabilities, contracting with domestic water utilities for water quality testing, and measuring arsenic will greatly contribute to the safety and reliability of tap water in Cambodia, PPWSA's ability to test water for arsenic, to be commissioned to test the water quality of domestic water utilities, and to measure arsenic will contribute greatly to further increasing the safety and reliability of tap water in the country.

If FL-AAS and AAS can be introduced, they will complement each other in measuring heavy metals, thereby establishing an efficient measurement system and backup system, and FL-AAS can be used for multiple heavy metal items when low concentrations are required in surveys.

5.4.2 Measurements with Lower Limits of Measurement, Accuracy, and Precision as Indicated in the NDWQS

(2) Methods of the same lower quantitation limits, accuracy, and precision as the method approved by NDWQS.		
	New analytical instruments to be introduced	**Items to be newly analyzed**
	Spectrophotometer (AS)	Ammonia (NH_3), Fluoride (F^-), Nitrate (NO_3^-), Nitrite (NO_2^-), etc.

PPWSA utilizes a measurement method for items such as ammonia and sulfate ions that uses a specific AS with a built-in pre-calibration curve and reagents dedicated to that AS. The advantage of this measurement method is that it is simple and does not require specialized knowledge. On the other hand, it may not be suitable for precision control and applicability. Preparation of reagents necessary for measurements at the laboratory, preparation of calibration curves for each measurement, and independent accuracy control are essential for water quality laboratories.

If the AS owned by the PPWSA is available for the preparation of calibration curves and standard measurement operations, it can be used. On the other hand, it is necessary to purchase standard reagents for the substance to be measured and reagents used in the process of measurement operations. It is also necessary to become proficient in the measurement operation.

5.4.3 Simultaneous Analysis of Inorganic Substances

(3) Simultaneous analysis of inorganic substances such as nitrate ion as indicated in the NDWQS.		
	New analytical instruments to be introduced	**Items to be newly analyzed**
	Ion chromatograph (IC)	Fluoride (F^-), Nitrate (NO_3^-), Chloride (Cl^-), Nitrite (NO_2^-), Sulfate ion (SO_4^{2-}), phosphate ion (PO_4^-), etc.

IC can measure multiple items for anions and cations in a single sample injection, enabling simultaneous analysis. The simultaneous analysis method has already been adopted by many analytical laboratories around the world, and by using IC for the measurement of ions, the technology and know-how of simultaneous analysis can be acquired. In addition, by attaching an automatic injection device to the IC, sample injection can be automated, which greatly improves the efficiency of analysis work.

5.4.4 Simultaneous Analysis of Agricultural Chemicals, Chlorine Disinfection By-Products, and Volatile Organic Compounds

(4) Simultaneous analysis of agricultural chemicals, chlorine disinfection by-products, and volatile organic compounds		
	New analytical instruments to be introduced	**Items to be newly analyzed**
	Gas chromatograph mass spectrometer	Agricultural chemicals such as pesticides and herbicides, Chlorine disinfection by-products (DBPs), Volatile organic carbons (VOCs), etc.

GC-MS is an analytical instrument widely used to measure pesticides and herbicides, chlorination byproducts, and volatile organic compounds. Simultaneous analysis of many kinds of agricultural chemicals such as pesticides is possible by pretreatment with an extraction device. Furthermore, by installing pretreatment devices such as purge & trap devices and headspace devices according to the substances to be measured, it is possible to measure chlorination byproducts, volatile organic compounds, and other substances. The items to be measured here are increasingly recognized as basic items in water quality analysis, and are positioned as analytical instruments that will be utilized more and more in the future. In the future, this method is expected to be utilized in the investigation of drinking water and its source. It can also be used to identify the causative agent and the location of the causative agent in the event of a leakage accident of toxic substances from factories, etc., and to investigate the degree of impact on health.

Analysis using GC-MS involves pretreatment. A solid-phase extraction system is often used as the pretreatment device, and the introduction of this device is mandatory. This device is independent of GC-MS. On the other hand, purge & trap devices and headspace devices are often attached to the GC-MS system. By attaching either one of these instruments to the GC-MS, chlorine disinfection byproducts, volatile organic compounds, etc. can be measured. Currently, GC-MS instruments are utilized with high frequency in WQCs in Japanese water supply, and PPWSA may in the future have a multiple instrument system with GC-MS accompanied by either a purge & trap device or a headspace device.

5.4.5 Simultaneous Analysis of Metal Ions

(5) Simultaneous analysis of metal ions	
New analytical instruments to be introduced	**Items to be newly analyzed**
Inductively coupled plasma mass spectrometer (ICP-MS)	Zinc (Zn), Selenium (Se), Nickel (Ni), Manganese (Mn), Lead (Pb), Arsenic (As), etc.

ICP-MS, like IC, is an analytical instrument capable of simultaneous analysis, automatic sample injection, and dramatically reduces the labor required to measure many types of metals. The lower limit of concentration that can be measured is also extremely low, making it possible to measure low concentration levels accurately and with high precision. In the past, there have been many cases of water contamination caused by heavy metals around the world, and even today, Cambodia's neighbors continue to deal with drinking water contamination caused by arsenic. Like GC-MS, it can be utilized in the event of water quality abnormalities, such as in the event of an accidental leakage of chemical substances from a factory.

5.4.6 Measuring New Substances of Concern in Tap Water

(6) Newly emerging substances which international organizations such as the WHO have raised concerns about.	
New analytical instruments to be introduced	**Items to be newly analyzed**
High performance liquid chromatograph mass spectrometer (LC-MS)	・Pesticides and herbicide which can not be measured by GC-MS methods. ・Newly emerging substances which international organizations such as the WHO have raised concerns about.

By utilizing LC-MS and GC-MS separately, an extremely wide variety of pesticides can be measured. This method can also be applied to chemicals that are feared to be newly present in the environment, making it highly useful.

5.5 Recommendations for Other Necessary Facilities, Equipment, and Personnel Enhancements

5.5.1 Necessary Facilities and Equipment

As a WQC, the building should be able to accommodate a physical and chemical testing room, an instrumental analysis room for installing the analytical instruments mentioned above, a pretreatment room for preparing analytical samples, a bacterial testing room, and a biological testing room. Each analysis room and compartment should be equipped with local exhaust ventilation, clean benches, drafts, etc., depending on the nature of the work, or be prepared to install such facilities when they become necessary. With the exception of the analytical instruments shown in "5.4 New analytical instruments to be introduced and the order in which they will be introduced" above, ***Table 5-5*** and ***Table 5-6*** of the general materials and equipment required for a WQC are shown in the below. The analytical equipment needed for the new WQC could use the same equipment and materials that PPWSA currently uses for water quality measurements. On the other hand, if water quality test is to be the responsibility of the new WQC while water quality measurements of water treatment plants and other facilities is to continue at the existing water laboratories, much of the analytical equipment will have to be newly purchased. Therefore, after determining the role and outline of the new WQC, a "list of necessary analytical equipment" should be considered.
(See 4.1.1(3) Equipment required at water quality testing centers (example for Japan))

Table 5-5 Analytical Instruments and Equipment of the WQC

Water sampling equipment	AS
Thermometer	Turbidimeter
Residual chlorine meter	DO Meter
Pure water production equipment	AAS
Balance	Mercury analyzer

Heater	ICP-AE
Shaker	ICP-MS
Electric constant-temperature dryer	IC
Distillation equipment	TOC meter
Vacuum pump	GC-MS
Electric furnace	LC
Refrigerator	LC-MS
Ultrapure water production equipment	Microscope
Centrifuges	High-pressure steam sterilizer
Solid-phase extraction equipment	Dry heat sterilizer
Conductivity meter	Thermostatic incubator
pH meter	

Source: JST

Table 5-6 Laboratory Facilities at the WQC

Draft chamber
Sink
Lab benches
Balance table
Clean bench
Instrument storage cupboard
Chemical storage cupboard
Floor sink
Air conditioning equipment
Ventilation fan
Experimental liquid waste treatment equipment
Electrical equipment
Gas facilities
Various high-pressure gas piping facilities

Source: JST

5.5.2 An Example of the Layout of the Main Test Facilities and Equipment

Figure 8 shows an example of the layout of the main test facilities and equipment assuming (1) the analytical instruments listed in "5.4 New analytical instruments to be introduced and the order in which they will be introduced" and (2) the area of the laboratory is 400 m^2. This is shown as "one example" and the actual construction should be designed in accordance with various factors and conditions. In addition to the testing rooms, other compartments such as warehouses, specimen storage rooms, and office rooms should also be provided.

The layout diagram shown in Figure 8 divides the testing room into 10 large sections, with the main testing facilities and instruments located in each section. In the section where analytical instruments are located, laboratory tables, apparatus and chemical cabinets are arranged, and clean benches and draft chambers are arranged depending on the use of the section. Dedicated compartments for biological and bacterial tests are also provided. Depending on the type of analytical equipment to be placed, the necessary local exhaust ventilation system should be installed. In this example, four draft chambers, 21 laboratory tables (including table with an attached sink), 15 sets of instrument and chemical cabinets, and two clean benches are arranged.

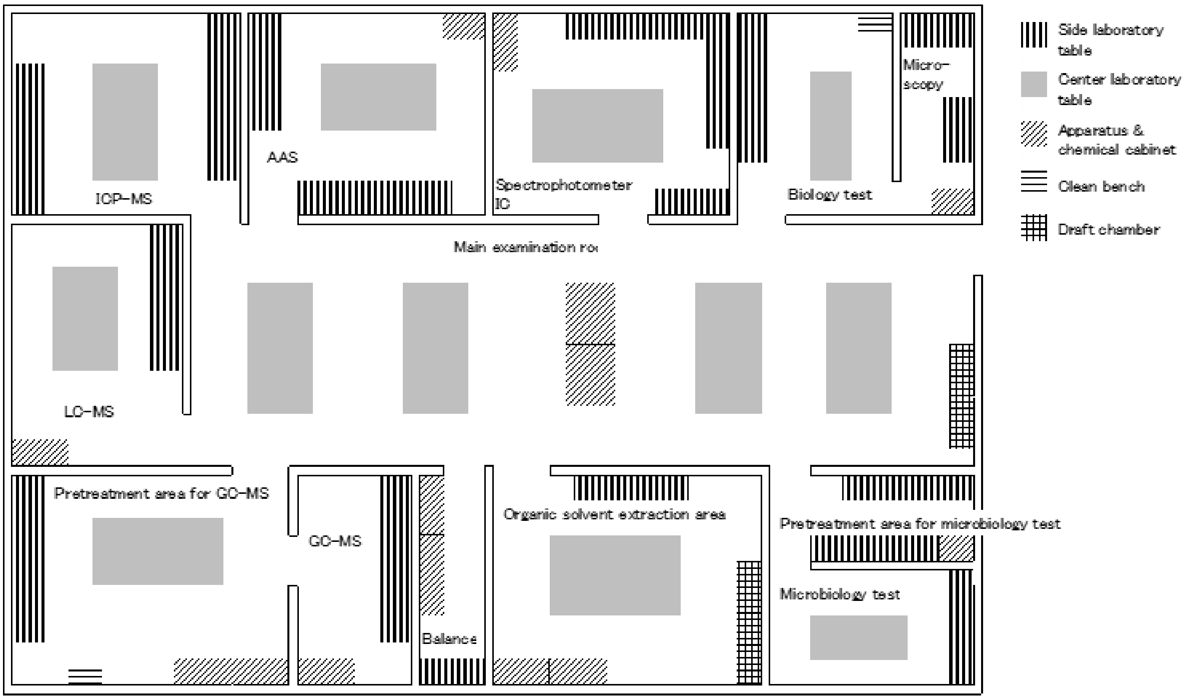


Figure 5-2 An Example of the Arrangement of Major Equipment at A Water Quality Laboratory
Source: JST

5.5.3 Cost of Major Analytical Instruments and Laboratory Equipment

Regarding the installation of the WQC, the PPWSA is considering locating the WQC within the existing water treatment plant, not in a separate WQC building, but in a complex multi-story building including office space. Therefore, this part shows the cost of purchasing major analytical instruments which will be installed for the first time for PPWSA, as well as major equipment for the WQC.

Table 5-7 shows the price ranges for the analytical instruments that are expected to be newly installed at WQC as described in "5.4", as well as for the major laboratory equipment shown in ***Table 5-7***. These prices were obtained from the websites 1)~3) shown in the footnotes to the table, which indicate price ranges for several different models.

Table 5-7 Price Range for Analytical Instruments and Laboratory Equipment

Instruments and equipment	price range (USD)
AS	8,000～12,000
FL-AAS	34,000～70,000
Mercury meter	10,000～40,000
IC	17,000～22,000
GC-MS	100,000～150,000
ICP-MS	160,000～240,000
LC	34,000～47,000
LC-MS	75,000～140,000
TOC meter	29,000～35,000
Laboratory table	3,500～7,000
Draft chamber	5,000～12,000
Clean bench	3,500～7,000

https://www.soran.net/, https://axel.as-1.co.jp/asone/s/C0000000/, https://www.wakenyaku.co.jp/ctg/
Source: JST

5.5.4 Developing human resources at the WQC

When a WQC is established, there will be cases where the existing work related to water quality testing may be changed, and in addition, new work will be required. In addition to the need to assign inspection personnel to the WQC, education and training for staff will be necessary because the work will be more complex than at present. The number of personnel required at the WQC depends largely on the nature of the work. On the other hand, the "water quality testing" that has been conducted by the water quality laboratories at each water treatment plant as a monthly test will be transferred to the WQC. Future roles and duties at the present water laboratories and the WQC should be newly established, and the number of personnel needed for each will be determined after workloads are finalized. This part summarizes the enhancement of human resources, including education and training for water quality testing personnel, in conjunction with the introduction of new analytical methods and analytical equipment.

(1) Education and training for new analytical instruments

When analytical instruments are newly introduced, it is necessary for the persons in charge of analysis to learn how to operate the instruments and control terminals as well as how to maintain and manage them on a daily basis, such as replacing consumable parts. They must also understand the analytical methods that use the equipment and learn the technical essentials and methods of analyzing the obtained data. On the other hand, it is desirable to have a system in place for manufacturers' technicians to perform major overhauls that are performed once every one to several years. ***Table 5-8*** shows the education and training methods for new analytical instruments.

Table 5-8 Education and Training Methods for New Analytical Instruments

Contents of Training	Methods of Training
Operation of analytical instruments (ex. AAS)	Training in the instruments manufacturer Training in a laboratory of foreign water utilities Use activity for making SOP as training
Maintenance of analytical instruments (ex. AAS)	Training in the instruments manufacturer Use activity for making SOP as training (Periodical preventive maintenance every a few years would leave to an instruments manufacturer or a licensed agency)

Source: JST

When new analytical equipment is introduced, the manufacturer or sales agent will provide detailed instruction manuals and explain to the person in charge or several water quality laboratory staff members how to operate the equipment using the actual equipment and how to perform daily maintenance, checks, and upkeep. This is a good opportunity to create an operation manual and a daily maintenance and inspection manual immediately before or after the introduction of the equipment. PPWSA's water laboratory has already obtained ISO 17025 accreditation for several items, and has established a system for understanding and maintaining SOPs for the operation of analytical equipment and methods for routine maintenance and upkeep.

(2) Education and training for the introduction of new analytical methods

PPWSA’s water laboratory has not used the analytical instruments shown in "5.4," and the pretreatment of collected samples, i.e., operations such as sample purification, concentration, and solvent conversion before the sample is injected into the analytical instruments, are new techniques that must be learned. It is also necessary to understand the measures taken to prevent contamination from the external environment (contamination) in pretreatment operations, since the concentration levels are lower than those previously measured in water quality laboratories. In addition, it will be necessary to acquire know-how on reagent preparation and storage methods, in addition to the preparation of calibration curves, which has not been done in the past. The education and training methods for the new analytical instruments and methods are shown in ***Table 5-9***.

Table 5-9 Education and Training Methods for New Analytical Methods

Contents of Training	Methods of Training
Analytical operation using fundamental apparatus (ex. Preparation of standard reagent)	Self training using chemical analysis text Training in a domestic analytical organization Training in a laboratory of foreign water utilities

Source: JST

It is most desirable that the acquisition of operations such as pretreatment, contamination prevention, and reagent preparation be trained through hands-on experience in a water quality analysis laboratory that actually performs similar analytical operations. Based on the results, it would be desirable to prepare a manual of water quality analysis methods according to the actual conditions of the PPWSA and use it in the WQC. Laboratories owned and operated by the manufacture or sales agent are not appropriate locations for these trainings, as they do not perform such operations. It is preferable that the training be received in the water quality laboratory of the water utility that has installed and is utilizing the analytical equipment that is the subject of the training. There is no such water quality testing laboratory owned by a water utility in Cambodia, and the training will be conducted outside of Cambodia. In addition, it is important that the training be timely and coincides with the installation of the equipment, to avoid delays in the operation of the analytical equipment or a time lag between the training and the installation of the equipment, which could result in some of the course content being missing .

In order for world-class water quality analysis technology for water supply to take root in Cambodia, it is desirable that training is first conducted in a timely and reliable manner at the point of instruments introduction, and that the content is substantial and appropriate. As mentioned above, since the training is expected to be conducted outside of Cambodia, it is possible to request an aid organization outside of Cambodia to conduct the training, and the Japan International Cooperation Agency (JICA) is a candidate. In this case, training in a third country, training in Japan or training in Cambodia by dispatching experts would be considered appropriate. Especially in Japan, more than 100 water utilities have already introduced GC-MS and other instruments and have been operating them for a long period of time, so training at such facilities is expected to be highly successful. At the same time, it is also possible to understand how to compile the output measurement results and how to perform statistics and analysis .

The training program, for example, the content of training for the initial introduction of AAS, such as reagent preparation, prevention of contamination, etc., can be applied to subsequent analytical operations using AS and IC. When GC-MS or ICP-MS is installed, each should have its own separate training content to ensure the reliable operation of the analytical instruments installed in the PPWSA.

5.5.5 Step-by-step implementation schedule

(1) Study of new WQC establishments plan

Regarding the establishment of the new WQC, it is necessary to study the whole plan of the new WQC. It is also desirable to consider the role of PPWSA as a leader in Cambodia's domestic water supply business, and to take into account its role as a driving force for Cambodia's water supply as a whole. The contents that should be included in the overall picture are: (1) plan for the introduction of analytical instruments, (2) securing the overall budget for the WQC, (3) details of analytical instruments to be installed, (4) required areas within the WQC, (5) outline of the WQC building, and so on. In developing an analytical equipment installation plan, it is important that it be consistent with the final overall picture. The overall budget for the WQC should consider the cost of all new WQC construction and equipment to be installed, and a multi-year budget execution should be budgeted or agreed upon within the PPWSA.

(2) Design, construction, and installation of the new WQC

For the construction of the WQC and the installation of analytical equipment, a proposal is presented that the assumed timeframe for the construction of the facility is one year, and the assumed timeframe for the phased installation of the new analytical equipment in three groups is five years.

Determine the number of compartments (analysis rooms), etc. that will be required in both cases of constructing a new WQC facility or upgrading rooms in an existing building to serve as the center, and based on the results, determine the outline of the building, installation site, and other construction work to be performed. The plan for the WQC construction will also be aligned with the plan for the installation of analytical equipment. During design and construction, in addition to the general facilities, it is important to consider the construction of exhaust-related equipment and devices required in each compartment and high-pressure gas piping required by analytical equipment at the same time or to make it easy to install them when necessary. An example of a proposed WQC construction is shown in ***Table 5-10***.

Table 5-10 Construction of Water Quality Testing Center Facility

	Activity	2024	2025	2026	2027	2028	2029
Formulation of the overall picture of the WQC							
	Introduction plan for analytical instruments						
	Securing the overall budget for the WQC						
	Details of equipment to be installed						
	Necessary sections within the WQC						
	Overview of construction work of the WQC						
Design and construction of the WQC							
	Plan of the WQC						
	Design of the WQC						

	Activity	2024	2025	2026	2027	2028	2029
	Construction of the WQC		→				

Source: JST

(3) Introduction of AAS and AS

The analytical instruments to be introduced are divided into three groups, each with a schedule of two models to be introduced at the same time. This point will be flexibly addressed depending on the results of the PPWSA study, budgetary measures, and other factors. The analytical instruments to be introduced in the first phase were set as AAS and AS.

In order to determine the model to be introduced, AAS and AS that are commercially available in Cambodia should be investigated. In general, in addition to the price of the equipment, the reliability, operability, robustness, ease of maintenance and procurement of maintenance parts, and service system of the dealer or agent will be investigated and considered. Demonstrations of measurement and maintenance operations using the target equipment at the manufacturer should also be included. At the same time, the existence of instruction manuals, languages used, operability, and methods of outputting measurement results should also be investigated for the terminal equipment used to control the equipment, set measurement conditions, and analyze data. Especially for AAS, the terminal equipment should be thoroughly investigated. If AAS and AS are planned to be installed early in the operation of the new WQC, the study for the above model determination can be started during the construction of the WQC to allow sufficient time for the study. AAS requires the installation of local exhaust ventilation and piping for several high-pressure gases for measurement.

After determining the model to be purchased, a training plan for measurement operation, maintenance, and upkeep should be developed. The training plan should mainly include training on operating methods from the manufacturer. The preparation of reagents and their storage are also important and necessary procedures in the actual operation of AAS and AS, therefore, it is necessary to ensure that the details of operational practices such as preparation and storage of reagents are mastered at any stage of the training plan. This is important to ensure that the equipment starts operating smoothly. Therefore, it is desirable that operational practices such as pretreatment of samples, preparation and storage of reagents, etc., be trained at an analytical laboratory that has experience in measurement work for the analytical instruments concerned. In parallel with or after the training, manuals for measurement operation, start check list, maintenance, etc. should be prepared. PPWSA has ISO 17025 accreditation, and it is sufficient to prepare documents (SOPs) in accordance with this ISO 17025 system.

When training is conducted at an external organization that has experience in measurement work using such analytical instruments, in addition to the routine inspection methods of the analytical instruments, information should also be collected on the long-term maintenance system including disassembly, cleaning, and repair by expert technicians with the manufacturer or agent, to be conducted at intervals of 1 to 3 years. Information will also be collected on specific implementation methods of accuracy control to ensure that reliable measurement results are always obtained. Based on these information, the procedures and systems will be described in the manuals as PPWSA procedures and systems in the manuals (SOPs) described above. An example of a proposed schedule for implementation is shown in ***Table 5-11***.

Table 5-11 Introduction of AAS and AS

	Activity	2024	2025	2026	2027	2028	2029
	Introduction of AAS		→	→			
	Survey of commercially available instrument and model selection		→				
	Research and requests regarding training		→	→			
	Implementation of training overseas or by dispatching experts			→			
	Deciding on the installation location and preparing surrounding equipment		→	→			
	Introduction of AS		→	→			
	Survey of commercially available instrument and model selection		→	→			
	Deciding on the installation location and preparing surrounding equipment			→			

Source: JST

(4) Introduction of IC and GC-MS

In order to determine the model to be introduced, AAS and AS that are commercially available in Cambodia should be investigated. The research shall be conducted in accordance with AAS. GC-MS is one of the most complex analytical instruments used for water quality testing in water supply in terms of structure, operability, and maintainability, and it is important to conduct necessary investigations on these points. The existence of instruction manuals, languages used, operability, and methods of outputting measurement results will also be investigated for the terminal equipment used to operate the equipment, set measurement conditions, and analyze data.

The pretreatment device to be attached to the GC-MS system depends on the analyte to be analyzed. Pretreatment devices include purge & trap devices, headspace devices, and solid phase microextraction devices. These pretreatment devices are also discussed in the research. GC-MS requires the installation of local exhaust ventilation and piping for the multiple high-pressure gases required for the measurement.

The training plan should be established as in the case of AAS implementation, and the necessary documents (SOPs) should be prepared based on the materials provided by the production manufacturer, etc. In particular, the operation of GC-MS is complex, and data analysis requires specific knowledge and some experience. It is important and desirable to receive training, including how to apply GC-MS measurement methods to the water supply field, at an external institution with a proven operational experience. Consider follow-up training at the time of installation, at the beginning of operation, or after some period of operation. The training plan should include an understanding of the long-term maintenance arrangements for analytical instruments, their long-term plans, and their actual experience. In addition, information on specific implementation methods of accuracy control to obtain reliable measurement results at all times will be collected and used as a system for PPWSA. As with the AAS, manuals and other documents related to measurement operation, maintenance, and upkeep will be prepared, and these will ensure that the necessary information from the training is included. An example of a proposed timeline for implementation is shown in ***Table 5-12***.

Table 5-12 Introduction of IC and GC-MS

	Activity	2024	2025	2026	2027	2028	2029
	Introduction of IC			→	→		
	Survey of commercially available instrument and model selection			→	→		
	Deciding on the installation location and preparing surrounding equipment				→		
	Introduction of GC-MS			→	→	→	
	Survey of commercially available instrument and model selection			→	→		
	Research and requests regarding training				→		
	Implementation of training overseas or by dispatching experts					→	
	Deciding on the installation location and preparing surrounding equipment				→		

Source: JST

(5) Introduction of ICP-MS and LC-MS

In order to determine the model to be introduced, ICP-MS and LC-MS that are commercially available in Cambodia should be investigated. he research will be conducted in the same manner as for GC-MS. ICP-MS, like GC-MS, is one of the analytical instruments used for water quality testing, and its structure, operability, and maintainability are complex, so the necessary research will be conducted on these points. The same investigation will be conducted for the terminal equipment as for GC-MS. LC-MS instruments can measure highly water-soluble pesticides and organic substances. It can also be applied to newly emerging trace organic substance issues. In the model selection research, referring research reports using LC-MS may be one of the efficient ways to do this. Understanding the use of LC-MS in the survey report is useful for understanding LC-MS and researching model selection. ICP-MS requires the installation of a local exhaust system and piping for the multiple high-pressure gases required for the measurement. LC-MS also requires piping for high-pressure gases, and the need for a local exhaust system will be investigated.

As in the case of the introduction of GC-MS, a training plan for ICP-MS should be established, and the necessary documents should be prepared based on the materials provided by the manufacturer or other organizations. As with GC-MS, operation of ICP-MS is complicated, and it is important to receive training and attend classes at an external institution that has experience in its operation. The training plan should include a long-term maintenance system for analytical instruments and its long-term plan and performance should be identified. Information will also be collected on specific methods of implementing accuracy control.

LC-MS is used to investigate water quality issues related to new substances that are reported to be present in trace concentrations and are of concern for health effects. Ensuring understanding of the conditions of use of LC-MS in these existing reports, etc., and then first receiving training in its use from the manufacturer, etc., will help smooth understanding of its operability. While accumulating experience in the use of LC-MS in PPWSA, it is possible to actively publicize the results of investigations not only domestically, but also internationally, and to establish a method of utilizing LC-MS in cooperation with laboratories and research institutes around the world. Similar to the implementation plan for AAS, GCC-MS, etc., manuals (SOPs) for measurement operation, maintenance, and upkeep will be developed, and these will ensure that the information obtained from the training and necessary items are included. An example of a proposed implementation schedule is shown in ***Table 5-13***.

Table 5-13 Introduction of ICP-MS and LC-MS

Activity	2024	2025	2026	2027	2028	2029
Introduction of ICP-MS				→	→	
Survey of commercially available instrument and model selection				→	→	
Research and requests regarding training					→	
Implementation of training overseas or by dispatching experts					→	
Deciding on the installation location and preparing surrounding equipment						
Introduction of LC-MS					→	→
Survey of commercially available instrument and model selection					→	→
Deciding on the installation location and preparing surrounding equipment						→

Source: JST

CHAPTER 6 CONCLUSION

6.1 Recognition of the Importance of Water Quality and Contribution to Community Development

If PPWSA were to establish a WQC equipped with these analytical instruments, it would have the capacity to measure all of the items listed in the NDWQS. As a result, PPWSA will be able to perform water quality testing that is currently outsourced to overseas laboratories. For water utilities in Cambodia, this will also allow them to outsource testing of all items in the NDWQS, which will further increase water users' confidence in the quality of their water supply. The PPWSA will be able to respond to sudden water quality abnormalities that may threaten the health of tap water users, such as chemical leaks into the water supply source, within its own country. The benefits to the PPWSA as well as to Cambodian domestic water utilities will be extremely significant.

As the top water supply authority in Cambodia, one of PPWSA's important responsibilities is to contribute to the development of the country's water supply industry. Therefore, in the initial development of the WQC, it is required to confirm the intentions of the national regulatory authorities, relevant organizations, and other water utilities. Then, with a view to future contracting of water quality testing, it is required to build an organization that will make this possible.

6.2 Importance of Establishing Advanced Laboratories and Increasing the Number of Parameters To Be Measured

Water quality tests conducted by water utilities in Japan and MWA in Thailand measure more than 100 chemical substances to confirm the safety of tap water. With the development of science and technology to date, new types of chemicals have been produced for the purpose of improving the convenience of daily life and such substances are now present in the environment. In addition, a wide variety of chemicals are used for efficiency and other purposes at the industrial and agricultural production stages. Furthermore, there have been a series of cases where chemical substances that were not previously recognized as a problem have accumulated in the environment, or where exposure to humans via tap water or food has begun to raise concerns about their hazardous effects on humans and other living organisms. It is important to address the concerns of water users about this situation, and to this end, it is necessary to continue to demonstrate that tap water is scientifically safe by conducting the necessary water quality tests and disclosing the results.

The testing of chemicals in multiple and trace concentrations is beginning to become a pressing issue worldwide, and it is necessary to establish a specialized laboratory with such capabilities for tap water in the country of Cambodia. It is important that the newly established laboratories in the PPWSA be able to test for a wide variety of chemicals in order to be able to respond to the various challenges that may arise now and in the future.

6.3 The Need for Human Resource Development and for Immediate Action to Achieve This

As indicated in "5.5.4 Developing human resources at the WQC," the biggest challenge for the newly establishing WQC is to develop human resources with the necessary knowledge and skills. The knowledge and skills required of personnel involved in water quality analysis are to understand and learn the operation and maintenance procedures of newly introduced analytical instruments, as well as the procedures for measurement methods using these instruments and the use of peripheral equipment. Furthermore, in order to effectively use the WQC to further establish the safety of tap water, it is important to develop and implement a plan for water quality measurements at all steps that make up the water supply, from the source to the tap. In order for such a water quality measurement plan to remain effective for the water supply, the measurement results must be properly analyzed and evaluated and reflected in future plans to protect water quality.

In order to quickly train the necessary personnel and establish an effective water quality management system in the PPWSA, training at water utilities that already have these experiences is strongly encouraged. One of the best training would be at places where advanced water quality management systems are already in place, such as water utilities in Japan and MWAs in Thailand, which are also included in this report.