UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Technical Guidelines for the
Development of Small Hydropower Plants

DESIGN

Part 8: Social and Environmental Impact Assessment

SHP/TG 002-8:2019

DISCLAIMER

Technical Guidelines for the
Development of Small Hydropower Plants
DESIGN

Part 8: Social and Environmental Impact Assessment

SHP/TG 002-8:2019

ACKNOWLEDGEMENTS

The technical guidelines (TGs) are the result of a collaborative effort between the United Nations Industrial Development Organization (UNIDO) and the International Network on Small Hydro Power (INSHP). About 80 international experts and 40 international agencies were involved in the document's preparation and peer review, and they provided concrete comments and suggestions to make the TGs professional and applicable.

UNIDO and the INSHP highly appreciate the contributions provided during the development of these guidelines and in particular those delivered by the following international organizations:

- The Common Market for Eastern and Southern Africa(COMESA)

- The Global Network of Regional Sustainable Energy Centres (GN-SEC), particularly the ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), the East African Centre for Renewable Energy and Energy Efficiency (EACREEE), the Pacific Centre for Renewable Energy and Energy Efficiency (PCREEE) and the Caribbean Centre for Renewable Energy and Energy Efficiency (CCREEE).

The Chinese government has facilitated the finalization of these guidelines and was of great importance to its completion.

The development of these guidelines benefited greatly from the valuable inputs, review and constructive comments as well as contributions received from Mr. Adnan Ahmed Shawky Atwa, Mr. Adoyi John Ochigbo, Mr. Arun Kumar, Mr. Atul Sarthak, Mr. Bassey Edet Nkposong, Mr. Bernardo Calzadilla-Sarmiento, Ms. Chang Fangyuan, Mr. Chen Changjun, Ms. Chen Hongying , Mr. Chen Xiaodong, Ms. Chen Yan, Ms. Chen Yueqing, Ms. Cheng Xialei, Ms. Chileshe Kapaya Matantilo, Ms. Chileshe Mpundu Kapwepwe, Mr. Deogratias Kamweya, Mr. Dolwin Khan, Mr. Dong Guofeng, Mr. Ejaz Hussain Butt, Ms. Eva Kremere, Ms. Fang Lin, Mr. Fu Liangliang, Mr. Garaio Donald Gafiye, Mr. Guei Guillaume Fulbert Kouhie, Mr. Guo Chenguang, Mr. Guo Hongyou, Mr. Harold John Annegam, Ms. Hou ling, Mr. Hu Jianwei, Ms. Hu Xiaobo, Mr. Hu Yunchu, Mr. Huang Haiyang, Mr. Huang Zhengmin, Ms. Januka Gyawali, Mr. Jiang Songkun, Mr. K. M. Dharesan Unnithan, Mr. Kipyego Cheluget, Mr. Kolade Esan, Mr. Lamyser Castellanos Rigoberto, Mr. Li Zhiwu, Ms. Li Hui, Mr. Li Xiaoyong, Ms. Li Jingjing, Ms. Li Sa, Mr. Li Zhenggui, Ms. Liang Hong, Mr. Liang Yong, Mr. Lin Xuxin, Mr. Liu Deyou, Mr. Liu Heng, Mr. Louis Philippe Jacques Tavernier, Ms. Lu Xiaoyan, Mr. Lv Jianping, Mr. Manuel Mattiat, Mr. Martin Lugmayr, Mr. Mohamedain SeifElnasr, Mr. Mundia Simainga, Mr. Mukayi Musarurwa, Mr. Olumide TaiwoAlade, Mr. Ou Chuanqi, Ms. Pan Meiting, Mr. Pan Weiping, Mr. Ralf Steffen Kaeser, Mr. Rudolf Hüpfl, Mr. Rui Jun, Mr. Rao Dayi, Mr. Sandeep Kher, Mr. Sergio Armando Trelles Jasso, Mr. Sindiso Ngwenga, Mr. Sidney Kilmete, Ms. Sitraka Zarasoa Rakotomahefa, Mr. Shang Zhihong, Mr. Shen Cunke, Mr. Shi Rongqing, Ms. Sanja Komadina, Mr. Tareqemtairah, Mr. Tokihiko Fujimoto, Mr. Tovoniaina Ramanantsoa Andriampaniry, Mr. Tan Xiangqing, Mr. Tong Leyi, Mr. Wang Xinliang, Mr. Wang Fuyun, Mr. Wang Baoluo, Mr. Wei Jianghui, Mr. Wu Cong, Ms. Xie Lihua, Mr. Xiong Jie, Ms. Xu Jie, Ms. Xu Xiaoyan, Mr. Xu Wei, Mr. Yohane Mukabe, Mr. Yan Wenjiao, Mr. Yang Weijun, Ms. Yan Li, Mr. Yao Shenghong, Mr. Zeng Jingnian, Mr. Zhao Guojun, Mr. Zhang Min, Mr. Zhang Liansheng, Mr. Zhang Zhenzhong, Mr. Zhang Xiaowen, Ms. Zhang Yingnan, Mr. Zheng Liang, Mr. Mr. Zheng Yu, Mr. Zhou Shuhua, Ms. Zhu Mingjuan.

Further recommendations and suggestions for application for the update would be highly welcome.

Table of Contents

Foreword

The United Nations Industrial Development Organization (UNIDO) is a specialized agency under the United Nations system to promote globally inclusive and sustainable industrial development (ISID). The relevance of ISID as an integrated approach to all three pillars of sustainable development is recognized by the 2030 Agenda for Sustainable Development and the related Sustainable Development Goals (SDGs), which will frame United Nations and country efforts towards sustainable development in the next fifteen years. UNIDO's mandate for ISID covers the need to support the creation of sustainable energy systems as energy is essential to economic and social development and to improving quality of life. International concern and debate over energy have grown increasingly over the past two decades, with the issues of poverty alleviation, environmental risks and climate change now taking centre stage.

INSHP (International Network on Small Hydro Power) is an international coordinating and promoting organization for the global development of small hydropower (SHP), which is established on the basis of voluntary participation of regional, subregional and national focal points, relevant institutions, utilities and companies, and has social benefit as its major objective. INSHP aims at the promotion of global SHP development through triangle technical and economic cooperation among developing countries, developed countries and international organizations, in order to supply rural areas in developing countries with environmentally sound, affordable and adequate energy, which will lead to the increase of employment opportunities, improvement of ecological environments, poverty alleviation, improvement of local living and cultural standards and economic development.

UNIDO and INSHP have been cooperating on the World Small Hydropower Development Report since year 2010. From the reports, SHP demand and development worldwide were not matched. One of the development barriers in most countries is lack of technologies. UNIDO, in cooperation with INSHP, through global expert cooperation, and based on successful development experiences, decided to develop the SHP TGs to meet demand from Member States.

These TGs were drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of these TGs may be subject to patent rights. UNIDO and INSHP shall not be held responsible for identifying any such patent rights.

Introduction

Small Hydropower (SHP) is increasingly recognized as an important renewable energy solution to the challenge of electrifying remote rural areas. However, while most countries in Europe, North and South America, and China have high degrees of installed capacity, the potential of SHP in many developing countries remains untapped and is hindered by a number of factors including the lack of globally agreed good practices or standards for SHP development.

These Technical Guidelines for the Development of Small Hydropower Plants (TGs) will address the current limitations of the regulations applied to technical guidelines for SHP Plants by applying the expertise and best practices that exist across the globe. It is intended for countries to utilize these agreed upon Guidelines to support their current policy, technology and ecosystems. Countries that have limited institutional and technical capacities, will be able to enhance their knowledge base in developing SHP plants, thereby attracting more investment in SHP projects, encouraging favourable policies and subsequently assisting in economic development at a national level. These TGs will be valuable for all countries, but especially allow for the sharing of experience and best practices between countries that have limited technical know-how.

The TGs can be used as the principles and basis for the planning, design, construction and management of SHP plants up to 30 MW.

- The Terms and Definitions in the TGs specify the professional technical terms and definitions commonly used for SHP Plants.

- The Design Guidelines provide guidelines for basic requirements, methodology and procedure in terms of site selection, hydrology, geology, project layout, configurations, energy calculations, hydraulics, electromechanical equipment selection, construction, project cost estimates, economic appraisal, financing, social and environmental assessments—with the ultimate goal of achieving the best design solutions.

- The Units Guidelines specify the technical requirements on SHP turbines, generators, hydro turbine governing systems, excitation systems, main valves as well as monitoring, control, protection and DC power supply systems.

- The Construction Guidelines can be used as the guiding technical documents for the construction of SHP projects.

- The Management Guidelines provide technical guidance for the management, operation and maintenance, technical renovation and project acceptance of SHP projects.

Technical Guidelines for the Development of Small Hydropower Plants-Design
Part 8: Social and Environmental Impact Assessment

1 Scope

This part of the Design Guidelines sets out the general principles, contents and requirements for an environmental impact assessment of an small hydropower (SHP) construction project. As countries typically have robust policies in place for social impact assessment, resettlement and soil and water conservation impact assessment, special studies are usually carried out by the departments designated by the country; this document only provides general technical guidance.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

SHP/TG 001, *Technical guidelines for the development of small hydropower plants—Terms and definitions*.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in SHP/TG 001 apply.

4 Environmental impact assessment

4.1 General provisions

4.1.1 The environmental impact assessment shall be carried out mainly in accordance with the relevant regulations, provisions, technical standards and specifications, as well as the planning and engineering technical documents relating to the relevant basin or area.

4.1.2 Environmental impact assessment factors including water environment, acoustic environment, air environment and soil assessment factors shall be selected on the basis of the technical standards and management requirements, to determine the assessment criteria. Assessment factors should be selected in accordance with the following principles:

a) Surface water environmental assessment factors may include water quality indicators, such as DO, pH, COD_{Mn}, BOD_5, NH_3-N, TN, TP, petroleum, and coliform group, and hydrologic runoff indicators, such as water surface area, water retention capacity, water temperature, runoff process, water depth, flow rate, and change of scour and silting, according to the water functions.

b) Underground water environmental assessment factors should be underground water level, pH, ammonia nitrogen, arsenic, permanganate index, nitrate, etc.

c) Acoustic environmental assessment factors shall be equivalent continuous sound level LEQ (A).

d) Air environmental assessment factors should be CO, NO_2, PM_{10}, TSP, etc.

e) Soil environmental assessment factors should be pH, TP, TN, organic matters, etc.

4.1.3 The environmental impact assessment standards may be divided into environmental quality assessment standards and pollution emission standards, which shall comply with the national and local quality control standards.

4.1.4 The environmental impact assessment grade and scope shall be determined on the basis of the classification criteria specified in the relevant technical specifications according to the scope and extent of both direct impact and possible indirect impact on the project. The assessment scope shall be determined on the basis of the assessment grade of each environmental element.

4.1.5 The focus of the social and environmental impact assessment shall be determined on the basis of the engineering characteristics, pollution discharge characteristics, and the operation mode and sensitivity of the environment protection objectives. Generally, the assessment mainly focuses on the barrier of river ecological system, runoff regulating effect and incurred influence on water environment and ecological environment caused by the engineering construction.

4.1.6 Environment protection objectives shall meet the following requirements:

a) Ecological environment protection objectives shall be defined on the basis of the current ecological environment status within the construction area and the protection requirements of the environmentally sensitive regions, including the protection objectives of both terrestrial ecology and aquatic ecology in terms of species, community and diversity.

b) Water environment protection objectives shall be defined on the basis of the water quality and the water volume requirements within the construction area and upstream and downstream water environmentally sensitive regions.

c) Atmospheric environment protection objectives shall be defined on the basis of the current atmospheric environment status within the construction area and the protection requirements of atmospheric environmentally sensitive regions.

d) Acoustic environment protection objective shall be defined on the basis of the current acoustic environmental status within the construction area and the protection requirements of acoustic environmentally sensitive regions.

4.2 Engineering analysis

4.2.1 Engineering analysis shall cover the conformity of the project with the relevant regulations and planning, the rationality of engineering environment, construction organization, project land occupation and resettlement, project operation, and the identification and selection of environmental impacts.

4.2.2 Environmental rationality analysis shall be undertaken from the perspective of general layout, development mode, water reservoir dam location, dam model, stock yard, spoil area, operation dispatching mode and ecological flow satisfaction, and the recommended or alternative scheme shall be proposed. If the basin is under cascade development, the feasibility and necessity of the connecting the project with the existing SHP project in terms of operation mode, ecological scheduling and requirements and ecological restoration measures of degraded river sections shall be analysed according to the current situation of existing hydropower stations in the basin.

4.2.3 The construction analysis shall meet the following requirements:

a) The volume of the waste slag shall be estimated on the basis of the earth-rock excavation and backfill, and the impact of the slag transportation and piling on the surrounding environment shall be analysed on the basis of the layout of the spoil area.

b) The intensity and impact scope of noise sources shall be analysed on the basis of the construction machinery and vehicle transportation, and the impact of construction vehicle transportation on the lives and traffic of local residents shall be analysed.

c) The discharge volume of domestic sewage, domestic garbage and production wastewater shall be estimated on the basis of the number of construction personnel and production water consumption, and the possible generating approaches and impact of pollution shall be analysed on the basis of the surrounding environmental status.

d) The impact of construction on irrigation, water supply, aquatic ecology and traffic transportation shall be analysed on the basis of construction diversion and general layout.

e) The impact approaches and scope of the construction on environmentally sensitive objectives shall be analysed and the impact on surface vegetation, topsoil resources and water loss, shall be also analysed on the basis of construction land occupation and surface disturbance.

f) The impact of construction activities on the habitats in environmentally sensitive areas and on the main flora and fauna in the region shall be analysed.

4.2.4 The possible social and environmental impact factors shall be analysed on the basis of inundation and land occupation, resettlement mode and migrant construction personnel. If the construction involves environmentally sensitive areas, religious, inter-state and international relationships, ethnic relationships, folk culture, cultural relics and landscape, the social and environmental constraints shall be analysed.

4.2.5 The impact of the construction on ecological, industrial and agricultural water consumption, water environment, existing hydropower station operation and scheduling, and the downstream ecological environment shall be anlaysed on the basis of the changes of water resources distribution, hydrological and sediment conditions and building obstruction.

4.2.6 All the environmental elements and factors which may be affected by the construction, and which have been restricted or affected by the existing projects or current environmental status shall be listed, and the nature and extent of such impacts shall be identified; the main environmental elements and factors shall be selected as important inputs for prediction and assessment, on the basis of the identification of environmental impacts. The environmental impacts may be identified and sorted by means of analogy analysis, matrix and expert judgement.

4.2.7 According to the type, location, sensitivity and scale of the project, as well as the characteristics and size of the potential environmental impact, the project environmental impact assessment may be divided into the following three levels:

a) 1st level: the project will have significant adverse environmental impacts that may extend beyond the scope of the project site or facilities. Its environmental assessment shall include the analysis of the potential positive and negative environmental impacts of the project, the comparison with other feasible alternatives (including a "no project" option), the proposal of various measures to prevent, reduce, mitigate or compensate adverse impacts and improve environmental performance, and the preparation of environmental impact assessment reports.

b) 2nd Level: the adverse environmental impact of the project on people or important environmental areas, including wetlands, forest, grasslands and other natural habitats, is less than the 1st level, and the scope of impact is limited to the project site. The environmental assessment shall include the potential positive and negative environmental impacts of the project and shall propose measures that may be used to prevent, reduce, mitigate or compensate for adverse impacts and improve environmental performance.

c) 3rd level: after environmental screening, the project has little or no adverse impact on the environment, and may not be subject to further environmental assessment.

4.3 Survey and assessment of environmental status quo

4.3.1 The survey and assessment of environmental status quo shall include the survey and assessment of regional environmental status quo, environmental quality and regional pollution source.

4.3.2 The survey and assessment of regional environmental status quo shall include the following content:

a) Topographical and geological survey, including topographical characteristics and types, geological structure, formation lithology and collapse, landslide, debris flow and other unfavorable geological phenomena.

b) Meteorological survey, including annual precipitation and its annual distribution, annual evaporation, wind intensity, predominant wind direction, extreme temperatures, rainstorm and other disastrous weather.

c) Hydrographic and sediment survey, including runoff and its composition, monthly average flow rate, monthly average sediment content, sediment grains gradation, low flow and flood characteristics.

d) River system survey, including surface water hydrological characteristics, division of water systems, water environment function zoning, water quality and water resources utilization, as well as the relationship between the main works of the project and the water system in the construction area. A map of the surface water system shall be attached. If there are dehydration sections up-and down-stream of the project, the length, scope, causes, and restoration of such sections shall also be surveyed.

e) Soil survey, including soil type, physicochemical property, and fertility.

f) Terrestrial organism survey, including the types, distribution, coverage, and dominant species of vegetation and the distribution and physiological and ecological habits of rare and endangered animals/plants; aquatic organism survey, including the composition and dominant species of fish, living habits of migratory fish, distribution of spawning grounds, types, quantity, habits, habitat distribution and protection levels of rare aquatic organisms in the waters affected by the construction.

g) Environmental sensitive area survey, including types, grade, geographic position, scope, function zoning, protection objects, protection requirements, and spatial relationship with the main works.

h) Water and soil loss survey, including types, causes, soil erosion modulus and treatment.

4.3.3 The survey and assessment of environmental quality status quo shall include following content:

a) The background quality of surface water environment, groundwater environment, ecological environment, acoustic environment and air quality environment shall be investigated. The regional environment quality shall be assessed on the basis of the survey of environment quality status quo, and the change trend of environmental quality shall be explained.

b) The environmental quality status quo shall be assessed by means of environmental quality status quo monitoring or recent routine environmental monitoring data. The environmental quality status quo monitoring shall comply with the relevant environmental quality monitoring standards, environmental protection standards and technical guidelines of social and environmental impact assessment.

c) Major regional environmental problems shall be surveyed, and the survey shall include water and soil loss, treatment of river dehydration sections caused by hydropower development, discharge management of pollution sources and water quality compliance, river ecological protection and ecological flow assurance, etc. The causes of major regional environmental problems and environmental constraints shall be analysed.

4.3.4 The survey and assessment of regional pollution sources shall include:

a) The main pollution factors and the characteristic pollution factors of water environmental quality in the surveyed region shall be selected as the main survey objects.

b) The pollution source survey shall include wastewater and sewage discharging outlet, agricultural non-point (diffused) source pollution, pesticide and fertilizer use, as well as the main sources of noise and air pollution.

4.4 Prediction and assessment

4.4.1 Basic requirements for environmental impact prediction and assessment shall include:

a) Environmental impact prediction and assessment scope shall be determined on the basis of the project characteristics and environmental characteristics, as well as local environmental protection requirements.

b) Environmental impact prediction and assessment should include construction period and operation period.

c) Assessment shall be conducted on the basis of the relevant environmental standards and environmental functional requirements. The environmental elements and factors that are not covered in any environmental standards should be assessed by environmental background value and thresholds.

d) The prediction and assessment shall mainly focus on the impact of hydrological regime, water temperature and water quality, river and lake ecosystem, and propose discharge process of ecological flow.

e) Environmental impact prediction may be conducted by means of mathematical model, physical model, analogy investigation, landscape ecology, graphic overlay and professional judgement.

4.4.2 The prediction and assessment shall comply with the following requirements:

a) If the project operation is likely to change the downstream hydrological regime, the impact of the construction on the water consumption of the downstream life, production and ecological environment shall be predicted. For the diversion power generation project or SHP station with a regulating reservoir, the satisfaction of downstream ecological flow shall be analysed. The composition and determination method of ecological flow are described in Appendix A.

b) The influence of water temperature stratified reservoir construction on water temperature shall be predicted, and the influence of low-temperature water discharge on downstream ecology and agriculture shall be analysed.

c) For an SHP project that is rated as "sensitive to" the groundwater environment, the groundwater environmental impact assessment shall be carried out.

d) The impact of reservoir inundation and project land occupation on land resources, cultural relics and historic sites, folk culture and landscape resources shall be predicted.

e) When resettlement is involved, the impact of such resettlement on the quality of life, employment, health care, education, infrastructure, religious and ethnic habits, community reconstruction, resettlement environment quality, and water and soil loss shall be assessed.

f) The impact of inundation, land occupation, resettlement, and construction activities on the habitats of wild plants, rare wild animals and endangered wild animals shall be predicted.

g) When there are rare fish, endangered fish, unique fish and migratory fish in the river where the project is located, the impact of project construction on such fish species shall be analysed.

h) When the project involves natural reserves and other environmentally sensitive areas, the impact on the protected objects, scope of protection and the structure and function of the environmentally sensitive areas and the impact on the river ecological system shall be predicted.

i) When it is preliminarily determined that the project may have an impact on environmental geology through geological survey, the impact of the project on landslides, bank collapse and other environmental geological conditions shall be predicted.

j) The impact of wastewater and soil erosion during construction, as well as the impact of construction on the ambient air, acoustic environment, solid waste and human health shall also be predicted.

k) Analyse the impact of the project on local employment, economic development, resource utilization and people's living conditions.

l) For the project with environmental risks, the source items of environmental risks shall be analysed, the consequence of environmental risks shall be calculated, and the environmental risk assessment shall be carried out.

4.5 Protection measures

4.5.1 Protection measures shall be technically feasible, economically reasonable, operationally reliable and assessible for the environmental protection objectives.

4.5.2 Protection measures shall meet the following requirements:

a) If the project operation affects downstream water consumption, measures for improvement and compensation shall be proposed and the ecological discharge facilities shall be set up.

b) If the water temperature layering affects the downstream agricultural irrigation or aquatic ecology, the stratified intake facilities or other water temperature restoration measures shall be set up.

c) If the project affects a groundwater sensitive area, protection measures for groundwater environment shall be proposed.

d) If the project construction affects rare wild animals/plants, transplantation and animal habitat, protection measures or rehabilitation shall be taken.

e) If the project construction affects sensitive areas such as nature reserves, protection or avoidance measures shall be taken.

f) The impact on migratory passages of fish shall be addressed by building fish passages or by artificial propagation and releasing.

g) Sewage treatment measures shall be proposed during construction period.

h) Dust fall and noise reduction measures shall be taken during construction period.

i) Health protection measures for workers shall be taken during construction period.

j) Risk prevention measures shall be proposed for the projects which involve environmental risks.

k) Protective or compensation measures shall be proposed to protect local culture, cultural relics and historic sites, and landscape.

4.6 Management and monitoring

4.6.1 Environmental management and monitoring shall be carried out according to the construction and operation periods. Environmental management measures, monitoring plans and environmental protection acceptance objectives shall be proposed.

4.6.2 In light of the impact characteristics of the construction project, corresponding monitoring plans for environmental quality, pollution sources, ecological and social environmental impacts shall be formulated.

4.6.3 For abnormal discharging and accidental discharging, especially environmental risks that may arise from accidental discharging, prevention and emergency response plans shall be proposed; for construction projects with long construction periods and wide impact scopes, specific requirements for environmental supervision during the construction period shall also be proposed.

4.7 Investment and analysis of economic gains/losses

4.7.1 The social and environmental protection investment estimation shall define a clear basis, expenses and standard. Total investment and annual investment arrangements shall be calculated on the basis of proposed protection measures quantities and expense standards.

4.7.2 The economic value of the social and environmental impact generated from the construction project shall be estimated from both positive and negative environmental impacts of the project in a qualitative and quantitative way, and this value shall be included in the cost-benefit analysis of the project as one of the basis for judging the feasibility of the construction project.

4.7.3 The predicted impact after the implementation of the construction project shall be compared with the social and environmental status quo. The social and environmental impact factors that are required, or possibly required, in economic assessment shall be selected from environmental elements, resource types and social culture. The quantified social and environmental impact shall be monetized, and the results shall be included in the economic analysis of the construction project.

5 Land acquisition and resettlement

5.1 Physical survey of land acquisition for construction

5.1.1 The scope of land acquisition for construction includes the project construction area and reservoir submerged area.

a) The project construction area includes the permanent structures such as the dam and power station, the land for external traffic, the management area and the scope of permanent land acquisition, as well as the land for the material yard, waste yard, operation area, temporary roads, construction camp, material transportation and transfer station, land for other temporary facilities and the area affected by construction blasting.

b) The submerged area affected by the reservoir includes the reservoir submerged area and the reservoir impoundment affected area.

1) The reservoir submerged area includes the regular submerged area below the normal storage level of the reservoir, and the temporary submerged area above the normal storage level of the reservoir caused by the flood backwater, wind and waves, boat wave, ice jam, etc.

2) The reservoir impoundment affected area includes the geological disaster area such as immersion, bank collapse, landslide, water logging, reservoir leakage caused by impoundment and other areas affected by reservoir impoundment, such as isolated islands, etc.

5.1.2 The designed flood standard for reservoir submerged objects is expressed with a recurrence period (year) and can be determined in accordance with Table 1.

Table 1 Designed flood standards for different submerged objects

Submerged object	Recurrence period (year)
Cultivated land, garden land	2～5
Woodland, grassland, unused land	Normal water level
Rural residential areas and towns, general towns and general industrial and mining areas	10～20
Medium city, medium industrial and mining area	20～50

5.1.3 The physical objects of land acquisition and migration refer to the population, land, buildings (structures), mineral resources, cultural relics and historical sites, municipal engineering, public facilities and infrastructure within the scope of land acquisition.

5.2 Resettlement planning

5.2.1 Resettlement planning includes resettlement tasks and methods, selection and design of the resettlement sites, infrastructure and supporting facilities of municipal public utilities and protection of the reservoir area.

5.2.2 In accordance with the regulations, an approach suitable for local natural conditions, social and economic conditions and the willingness of migrants shall be selected to determine the resettlement objectives.

5.2.3 Migrant resettlement tasks shall be determined by the population to be resettled, including production resettlement population and relocation resettlement population, and meet the following requirements:

a) The production resettlement population shall refer to the population who need to rearrange production modes due to the loss of land and other means of production caused by the project construction.

b) The relocation resettlement population shall refer to the population must move out and be relocated due to the project construction.

c) The resettlement population in the base-year shall be determined by on-site investigations combined with relevant local regulations.

5.2.4 The natural growth rate of the population from the survey base-year to the design level year shall be considered in the resettlement of migrants, which may be determined according to the Formula (1).

$$B = B_0(1 + R)^{(n_1 - n_2)} \qquad \text{......(1)}$$

where

B is the population at the design level year, in person;

B_0 is the population at survey base-year, in person;

n_1 is the design level year, in year;

n_2 is the survey base-year, in year.

5.2.5 The resettlement target refers to the overall level that may be achieved in the design level year after resettlement, including economic development goals and social development goals. The resettlement target shall be determined in line with the principle that the production and living standards after resettlement have reached or exceeded the original level before the relocation, and the specific content shall include:

a) Economic development goals include per capita net income, per capita food availability, etc.

b) Social development goals include development goals for social utilities and infrastructure in the resettlement areas.

5.3 Compensation investment

5.3.1 The calculation of compensation investment shall be based on the relevant laws and regulations of the national and local government, and the results of physical surveys of land acquisition and resettlement planning for construction, mainly including compensation subsidies, project construction fees and other expenses.

5.3.2 Compensation subsidies mainly include land compensation and resettlement fees, temporary acquisition land compensation fees, housing and ancillary building compensation, compensation for house decoration, plant compensation, forest compensation, agricultural and sideline facilities compensation fees, industrial enterprise compensation fees, relocation allowances, poor-migrant housing subsidies, culture and education and health subsidies, and relocation transitional allowance.

5.3.3 The project construction fee includes costs of infrastructure projects and professional projects, protection projects and reservoir bottom cleaning in the resettlement area.

5.3.4 Other expenses include pre-work fees, comprehensive survey and design fees, consulting service fees, technical training fees, taxes, etc.

6 Soil and water conservation

6.1 Objectives and requirements of soil erosion control

6.1.1 The scope of disturbed land caused by the project construction shall include permanent and temporary land acquisition and other land managed and used.

6.1.2 Objectives of soil erosion control include:

a) Artificial disturbance to the original landform shall be minimized.

b) Soil erosion caused by project construction shall be effectively controlled.

c) The abandoned slag shall be stored in the slag yard and protective measures shall be taken.

d) After construction, except for permanent structures and water surface, other lands shall be restored to vegetation or original land-use functions.

e) Riparian vegetation shall be restored in all areas wherever feasible.

6.2 Measures system for soil erosion control

The prevention and control measures for soil erosion mainly include slag retaining projects, slope protection projects, land improvement projects, flood control and drainage projects, precipitation and seepage storage projects, wind prevention and sand control projects, vegetation restoration and construction projects and temporary projects. Corresponding prevention and control measures shall be taken according to the actual situation of the project.

6.3 Investment in soil and water conservation

The costs in soil and water conservation include engineering measures fee, plant measures fee, temporary measures fee, miscellaneous fee and other expenses stipulated by the state.

7 Social impact assessment

7.1 Social impact assessment shall be conducted through public participation. Objectives of public participation shall include affected residents and groups (stakeholders), competent authorities, experts and social organizations, and shall meet the following requirements:

a) Methods and procedures for hearing their comments shall be determined.

b) Public participation comments shall be analyzed, main conclusions shall be drawn, and make it clear whether the opinions are adopted or not, and the reasons shall be clarified.

7.2 The investigation of social environmental status quo shall include the population, land, employment, income, public facilities, public health amenities, religion and nationality, community structure, cultural relics and historic sites, and landscape resources in the affected area.

7.3 On the basis of the investigation of social environmental status quo, the objectives of social environmental protection shall be proposed according to local living standards, religious and ethnic customs, and the protection of the rights of residents affected by the proposed project.

8 Conclusion of assessment and advice

Conclusion of assessment and advice shall meet the following requirements:

a) Summarize all the assessment work.

b) The relationship between production and living activities in this construction project and local community and environment during different implementation phases shall be summarized concisely, accurately and objectively.

c) The social and environmental impact of the construction project under normal and specific circumstances shall be clarified, and protection measures shall be proposed.

d) Conclusions from public participation shall be considered.

e) Conclusion as to whether the construction project is feasible from the perspective of social and environmental protection shall be arrived at.

Appendix A
(Normative)
Calculation method of ecological flow of SHP station

A.1 Water demand necessary for maintaining stability of the aquatic ecosystem

The water demand necessary for maintaining the stability of an aquatic ecosystem may be calculated by the hydrological method, the hydraulics method, the combination method, the comprehensive method and the ecological hydraulic method.

A.1.1 Hydrological method

The hydrological method is based on the historical flow and determines the ecological water demand of the river based on simple hydrographic indicators. The most commonly used representative methods include the Tennant method and the minimum monthly average run-off method.

A.1.1.1 Tennant method

a) Calculation method: on the basis of the hydrological data, the conditions of flow in a river is expressed by the annual average run-off percentage.

b) Protection objectives: fish, aquatic birds, mammals, reptiles, amphibians, molluscs, aquatic invertebrates and all relevant life forms which compete for water with human beings.

c) Calculation standard:

Table A.1 Flow rates of rivers with protected fish, wild animals, recreational purposes and environmental resources

Description of flow conditions	Recommended base flow (low flow period) (% average flow rate)	Recommended base flow (high flow period) (%average flow rate)
Inundation or maximum		
Best scope	60～100	60～100
Very good	40	60
Good	30	50
Moderate	20	40
General or poor	10	30
Bad or minimum	10	10
Extremely bad	0～10	0～10

d) Basic requirements:

1) According to different areas, different water demand and different protection objects, a series of hydrological data shall be carefully analysed; data on relevant river sections shall be analysed; and flow rate standards shall be adjusted make the adjusted flow conform to the local river situation.

2) Aquatic organisms have different flow rate requirements in different seasons. The discharging flow duration curve within the year shall be prepared on the basis of different flow rate requirements in different months and different seasons in the ecological system, and the curve shall meet the habitat requirements of the relevant aquatic organisms.

e) Scope of application: the hydrological method may be used for the initial objective management and strategic management of the river.

A.1.1.2 Minimum monthly average run-off method

a) Calculation method: the multi-year average value of the minimum monthly average measured run-off is taken as the basic ecological environmental water demand of a river:

$$W_b = \frac{T}{n}\sum_{i=1}^{n}\min(Q_{ij}) \times 10^{-8} \quad \text{(A.1)}$$

where

W_b is the basic ecological environment water demand of river, in 10^8 m^3;

Q_{ij} is the monthly average flow rate of Month j in Year i, in m^3/s;

n is the statistical years;

T is the conversion coefficient, for which the value is 31.536×10^6 s.

b) Assumed conditions: Under this flow rate, the downstream water demand may be satisfied, and the flow of the river may not get interrupted.

c) Scope of application: it is applicable to arid and semi-arid areas and rivers with complex ecological environmental objectives. The calculation result may be relatively large for a region with a relatively single ecological environment objective.

A.1.2 Hydraulics method

The hydraulics method is a model designed by the standard of habitat protection type, mainly including the wetted perimeter method and the R2-CROSS method based on hydraulic parameters.

A.1.2.1 Wetted perimeter method

a) Calculation method: the wetted perimeter (See Figure A.1) is adopted as a quality indicator of habitat, and is used to draw a wetted perimeter-flow rate curve for the critical habitat area (usually shoal); it determines the recommended flow rate of the river at the turning point of the curve (See Figure A.2).

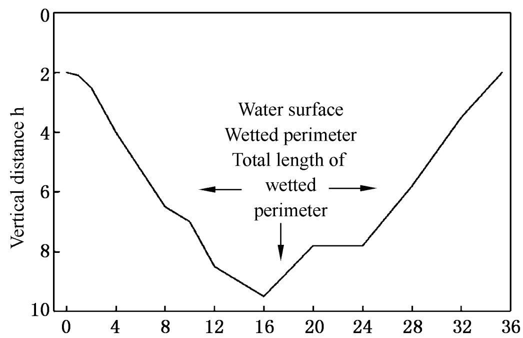
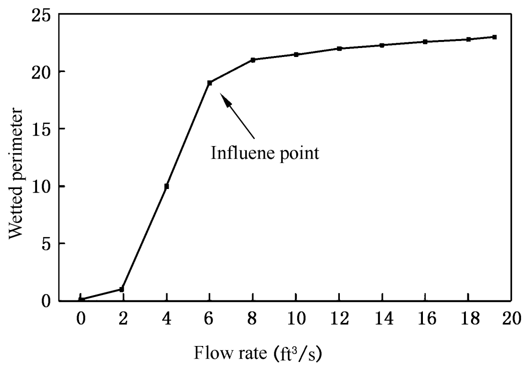


Figure A.1—Definition of the Wetted Perimeter



NOTE

lft^3 (cubic feet) = 0.028 316 8 m^3

Figure A.2—Wetted Perimeter-Flow Rate Relationship

b) Constraints: The wetted perimeter method is greatly influenced by the shape of the river. For example, the curve of a triangular river does not show significant growth changes; whereas rivers where the riverbed shape varies over both distance and time cannot be represented in a stable wetted perimeter-flow rate curve and hence the fixed relationship may not be established.

c) Scope of application: it is applicable to wide-shallow rectangular and parabolic rivers with stable riverbed shape.

A.1.2.2 R2-cross method

a) Calculation method: the river width, average water depth, average flow rate and wetted perimeter rate are used to evaluate the protection level of the river habitat and thus determine the river target flow. In this method, the wetted perimeter rate is the percentage of a wetted perimeter of a cross section at a flow rate to the full wetted perimeter at the multi-year average flow rate.

b) Calculation standard

Table A.2 Standard for determining minimum flow rate with the R2-cross method

River top width (m)	Average water depth (m)	Wetted perimeter rate/%	Mean velocity (m/s)
0.3～6.3	0.06	50	0.3
6.3～12.3	0.06～0.12	50	0.3
12.3～18.3	0.12～0.18	50～60	0.3
18.3～30.5	0.18～0.3	⩾70	0.3

c) Constraints

1) The flow of a seasonal river cannot be ascertained.

2) Lower precision: on the basis of the measured data of a river cross section, the relevant parameters are determined to represent the whole river, which is prone to errors, and the calculation results are greatly affected by the selected cross section.

3) Single standard: the hydraulic parameters of both triangular rivers and wide-shallow rivers are based on the same standard.

4) Small standard scope: the standard scope is for 18 m to 30 m in river width.

d) Scope of application: it is applicable to small perennial rivers. It also provides the hydraulic basis for other methods.

A.1.3 Combination method (hydrological-biological analysis method)

a) Calculation method: the multi-variate regression statistical method shall be used to establish a relationship between the initial biometric data (species biomass or diversity) and environmental conditions (flow, flow velocity, water depth, chemical contents, and temperature) to judge the organisms' demand for the river flow and the impact of flow changes on the biotic population.

b) Objects of study: fish, invertebrates (insects, crustaceans, and molluscs) and large plants (advanced plants).

c) Scope of applicable: it is applicable to the rivers which are less affected by human beings.

A.1.4 Ecological hydraulics method

A.1.4.1 Calculation method:

a) This is a habitat simulation method that determines the appropriate flow rate in a hydraulic habitat adapted by aquatic organisms. It is assumed that water depth, flow velocity, wetted perimeter, water surface width, cross-sectional area, water surface area and water temperature are the main hydraulic habitat parameters that impact the quantity and distribution of species by flow rate change, and the torrents, slow flows, shoals and deep pools are the main hydraulic parameters for such impact.

b) The model is divided into three parts (see Figure A.3). The first part is a description of the river aquatic habitat. This module analyses the most basic survival requirements of aquatic organisms on the parameters of water depth, velocity and other hydraulic habitats; the impact of water temperature change on aquatic organisms; and the basic survival requirements of aquatic organisms on torrent and other hydraulic forms. The second part is a river hydraulic simulation. This uses 1D, 2D or 3D hydraulic models to simulate the hydraulics of the studied river section and calculates changes in the hydraulic habitat parameters of the section under different flow rates. The first and second modules are then analysed to develop a hydraulic habitat indicator system. The third module is making decisions on the river aquatic ecological flow rate. Professionals engaged in hydrographic resources, hydraulics, environmental assessment and aquatic ecology determine the river's ecological flow on the basis of the hydraulic habitat indicator system, combined with the process of coming water, local socioeconomic development status and policies.

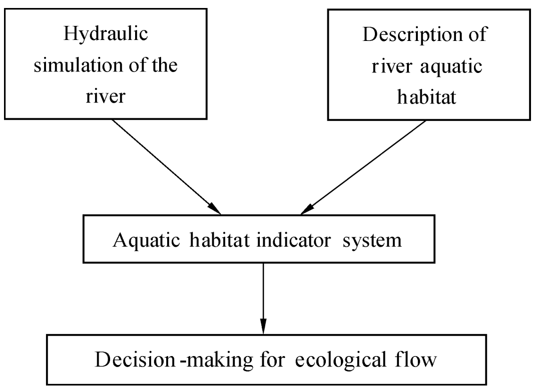


Figure A.3—Schematic diagram for the ecological hydraulic method

A.1.4.2 Indicator system for low flow period:

a) Full-stream hydraulic habitat parameters: Calculate the hydraulic parameters for different sections of the river with varying lengths and determine the percentage of each river section length with respect to the length of the whole river section. This eliminates erroneous judgements based solely on the parameters of a small section of river that forms a very small percentage of the whole river length.

b) Water surface area: Calculate the water surface area under different flow rates and the percentage of surface area under multi-year average flow rate in the low flow period.

c) Hydraulic form: Calculate the number of sections with slow flow, torrential flow, relatively torrential flow, and relatively slow flow, under different flow rates, and determine their total length and respective percentage of the total section length. Calculate the number of shoals and deep pools under different flow rates.

d) Water temperature: Establish a monthly full stream water temperature change curve; list monthly water temperatures under different flow rates at the cross sections where extreme water temperatures occur.

e) Annual changes of hydraulic habitat parameters such as the water depth in typical section: Compare the annual variations of hydraulic habitat parameters at the cross sections where large tributaries join the main stream.

A.1.4.3 Standards for indicators:

Table A.3 Standards for determining the hydraulic habitat parameters of large rivers under minimum flow rate with the ecological hydraulics method

Habitat parameter indicator	Minimum standard	Percentage of accumulated river section length, per cent
Maximum water depth	2-3 times body length of fish	95
Average water depth	⩾0.3 m	95
Average speed	⩾0.3 m/s	95
Water surface width	⩾30 m	95
Wetted perimeter rate	⩾50%	95
Flow crosssection area	⩾30 m^2	95
Water surface area	⩾70%	
Water temperature	Suitable for survival and reproduction of fish	
Habitat form indicator	Concept definition	

Table A.3 (*continued*)

Habitat parameter indicator	Minimum standard	Percentage of accumulated river section length, per cent
Torrential flow	Average flow rate ≥1 m/s	No big change in section number, the length of accumulated river length with torrential flow and relatively torrential flow is reduced <20
Relatively torrential flow	Average flow rate 0.5 m/s~1 m/s	
Relatively slow flow	Average flow rate 0.3 m/s~0.5 m/s	
Slow flow	Average flow rate ≤0.3 m/s	
Deep pool	Maximum water depth ≥10 m	No big changes in number
Shoal	River bank slope ≤10°, water depth within 5 m scope ≤0.5 m	

A.1.4.4 Scope of application: it is applicable for calculation of ecological flow rates of large and medium rivers. For medium rivers, the above-mentioned standard may be adjusted downwards appropriately.

A.2 Minimum diluted and purified water volume needed to maintain river water environment quality

A.2.1 7Q10 method

The average water volume that has a 90 per cent chance of lowest flow for seven consecutive days is used as the minimum design river flow rate.

A.2.2 Stable water quality model

Taking each sewage outlet of the river as the boundary line, the river is divided into several sections. For general inland river sections, the formula of allowable pollutant discharging quantity is:

$$W_i = C_s(Q_0 + q_i) - C_0 Q_0 \exp\left(-\frac{Kx_i}{u}\right) \quad \cdots\cdots (A.2)$$

For tidal river sections and networked sections, the formula of allowable pollutant discharging quantity is:

$$W_i = C_s(Q_0 + q_i) - C_0 Q_0 \left[\exp\left(-\frac{u}{2E_x}(1 - \sqrt{1 + 4KE_x/u^2})\, x_i\right)\right] \quad \cdots\cdots (A.3)$$

As for the whole river section, the total allowable quantity of pollutants, W, is the sum of the allowable quantity of pollutants for each river section, W_i.

Where

W_i is the allowable discharging quantity of pollutants for a river section i, in g/s;

C_S is the water environment quality standard for concentration of pollutants from a cross section, in mg/L;

Q_0 is the upstream incoming flow rate, in m^3/s;

q_i is the sewage flow rate of river section i, in m^3/s;

C_0 is the concentration of pollutants in water coming from upstream, in mg/L;

K is the Pollutantattenuation coefficient, in d^{-1};

x_i is the combined length of river section i, in m;

u is the average flow rate of water body, in m/s;

E_x is the longitudinal dispersion coefficient, in cm^2/s.

A.2.3 Environmental functioning method

This method is used to calculate the water demand to meet the river water dilution, self-purification and other environmental functions, on the basis of the water quality protection standards and the concentration of discharging pollutants.

Divide the river (river section) into i small sections, and assume each small section as a closed catchment area. On the basis of the water-volume balance method and water quality model, calculate the river water demand of each section, Q_{vi} ($i = 1, 2, \cdots, n,$), and then add these together to obtain the environmental water demand for the whole river (river section). Q_{vi} shall meet the following equations:

$$\begin{aligned} Q_{vi} &\geqslant \lambda \times Q_{wi} \\ Q_{vi} &\geqslant Q_{ni}(p) \end{aligned} \qquad \cdots\cdots (A.4)$$

where

λ is the river-diluting coefficient;

Q_{wi} is the reasonable total sewage discharging quantity of i small sections, referring to the volume of sewage that meets the discharging standards;

$Q_{ni}(p)$ is the flow rate of i small sections under guaranteed rates (monthly guaranteed rate, e.g. $p_0 = 90\%$, or $p_0 = 80\%$) designed for different hydrological years (such as multi-year average, low flow year, and normal flow year).

A.3 Sediment-transport water demand for the river

$$W_i = S_i / \frac{1}{n}\sum_{i\neq 1}^{n}\max(C_{ij}) \quad \cdots\cdots (A.5)$$

where

W_i is the sediment transport water demand, in m^3;

S_i is the multi-year average sediment volume, in m^3;

c_{ij} is the monthly average sediment content of Month j in Year i, in m^3;

N is the statistical years.

A.4 River evaporation water demand

$$V = H_0(A - P) \quad \cdots\cdots (A.6)$$

where

V is the net evaporation loss of water during observation period, in m^3;

H_0 is the evaporation depth of water surface during observation period, in m;

A is the average impoundment area of water during observation period, in m^2;

P is the precipitation during observation period, in m.