



UNITED NATIONS  
INDUSTRIAL DEVELOPMENT ORGANIZATION



# Technical Guidelines for the Development of Small Hydropower Plants **DESIGN**

## **Part 11: Report Preparation**

**SHP/TG 002-11: 2019**



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Development of Small Hydropower Plants  
**DESIGN**

## **Part 11: Report Preparation**

**SHP/TG 002-11: 2019**

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

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## 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](http://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 30MW.

- 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 11: Report Preparation**

# 1 Scope

This part of the Design Guidelines stipulates the principles, contents, requirements and outlines of different reports required for small hydropower (SHP) projects at the pre-feasibility study and feasibility study stages.

## 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 Report compilation principles

4.1 The laws and local regulations of the country shall be used as the legal basis for the compilation of the report.

4.2 Data and materials cited shall be authentic, accurate, reliable and effective.

4.3 Technical contents shall be consistent with the relevant regulations and requirements of SHP/TG 002.

## 5 Guidelines for the pre-feasibility study report

5.1 The pre-feasibility study report is a professional document for the new development of SHP projects. It should include:

- a) The basis of, and reasons for, proposing the project;
- b) Reasons for site selection, including site characteristics, potential problems and solutions;
- c) A general framework for the proposed investment project;
- d) Technical and economic analyses, and evaluation of the proposed investment project.

5.2 The contents of the pre-feasibility study report shall meet the following requirements:

- a) To demonstrate the necessity of engineering construction, and determine the scope and sequence of engineering tasks and comprehensive utilization of resources.
- b) To collect topographical data of rivers and surrounding areas, and demonstrate the preliminary rationale of site selection.
- c) To determine the preliminary main hydrological parameters and results according to the analysis and calculation of hydrological basic data.

- d) To investigate, preliminarily, and analyse the geological conditions and main engineering geological problems in the project area.
- e) To determine, preliminarily, the scale and development mode of the project.
- f) To select preliminary construction sites (dam/diversion site, intake site, plant site) for the main structures and preliminarily formulate the overall layout of the project and the basic type of main structures.
- g) To select, preliminarily, the type, quantity, and layout plan of generating sets.
- h) To work out the main electric connection scheme, and the model selection plan and layout plan of other electromechanical equipment.
- i) To select, preliminarily, the hydro mechanical structure and layout plan.
- j) To formulate, preliminarily, the construction diversion mode, construction scheme of main works, external traffic scheme, and the construction general layout and total duration.
- k) To evaluate, preliminarily, the impact of engineering construction on society and environment.
- l) To estimate project investment.
- m) To evaluate preliminarily economic cost-effectiveness and provide financial appraisal.

5.3 The pre-feasibility study report shall be prepared in accordance with the outline provided in Appendix A.

## **6 Guidelines for the feasibility study report**

6.1 The feasibility study report is an outcome report that demonstrates the technical feasibility and economic rationality of the project on the basis of the pre-feasibility study report. It should include the following:

- a) Review the concluding observations in the pre-feasibility study phase.
- b) Provide applicable plans, countermeasures and preliminary drawings for project implementation.
- c) Provide sufficiently accurate quantities and costs for the project.
- d) Further evaluate the project value from the perspective of resource allocation and provide the economic appraisal.
- e) Further evaluate project profitability from the perspective of investors and carry out a financial evaluation.

6.2 The contents of the feasibility report shall meet the following requirements:

- a) Collection of relevant policies of the country, as well as information about social organizations' support for the project.
- b) Re-checking and determination of the project tasks and scale, the project operation principles and modes, and re-checking of adopted values for design of ground motion parameters and the corresponding seismic design intensity.
- c) Re-checking and determination of hydrological parameters and results.
- d) Investigation of geological conditions of the reservoir and the project area, and evaluation of any geological problems with the project.
- e) Determination of the design flood standards and the general layout of the project, as well as the relative

position, structural type, control size, control elevation and work quantity of selected structures.

- f) Determination of the type, quantity, basic parameters and layout plan of the turbine. Determine the type, quantity, main technical parameters and layout plan of the turbine accessory equipment and auxiliary systems;
- g) Determination of the power transmission voltage level and transmission scheme, the main electrical connection scheme, and the type, specifications, main technical parameters, quantity and layout of the selected electrical equipment.
- h) Selection of types, quantities, main technical parameters, dimensions and layout of hydro mechanical structures including various types of gates, trash racks, valves and hoisting equipment.
- i) Re-checking of the construction diversion mode; determine the structural design of the diversion structures, the construction scheme of main works, the general layout of construction sites and the controlling duration, and submit the basis for preparation of construction conditions.
- j) Re-checking of the impact of engineering construction on society and the environment, and determine the design of environmental protection measures.
- k) Determination of design estimates for the engineering element; put forward the general design estimate for the project.
- l) Re-checking of the economic appraisal indicators.

6.3 The feasibility study report shall be prepared in accordance with the outline given in Appendix B.

# **Appendix A (Normative) Outline for pre-feasibility study report**

## **Chapter 1 Overview**

1. Project geographical location, planning results for the river where the project is to be located, approval opinions and the compilation process for this document.
2. Results or conclusions of the site selection report are briefly described.
3. Results of the pre-feasibility study are briefly described.
4. Investment environment and project background (if necessary) are briefly described.
  - a) Collect relevant policies of industries, enterprises, taxation and investment in the country, as well as the role that non-governmental organizations can play in the SHP industry. Analyse the investment environment in the project area.
  - b) Provide background information of the project and information about potential investors.
5. Conclusions and recommendations.
6. Drawings and tables attached are to include:
  - a) Project position schematic diagram;
  - b) Hydropower development status and planning schematic diagram (plan, cascade longitudinal plan) of the river (section) where the project is located;
  - c) Table of project features.

## **Chapter 2 Project construction necessity and tasks**

1. Demonstrate the necessity of the project in terms of resource conditions, social economy and development planning.
2. Demonstrate tasks and the order of engineering construction.

## **Chapter 3 Construction conditions and site selection evaluation**

1. Briefly describe the topography, landform and traffic situations of the preliminarily selected site.
2. Hydrology
  - a) Briefly describe acquisition conditions, methods and quality of hydrological data.
  - b) Analyse data of runoff, flood and sediment, and provide preliminary results.
  - c) Attach drawings and tables to include:
    - 1) Watershed system and hydrological network distribution diagram;
    - 2) Annual runoff or rainfall results table and frequency curve chart;
    - 3) Design storm or flood peak frequency curve chart.

### 3. Engineering geology

- a) Briefly describe regional geological conditions, and the geological conditions and major geological problems of reservoir areas and main project structures.
  - b) Put forward geological conclusions and suggestions.
  - c) Attach a regional geological map or structure outline map.
4. Preliminarily evaluate site construction conditions.

## **Chapter 4 Characteristic water level and installed capacity**

1. Preliminarily determine the reservoir characteristic water level according to river basin conditions and technical and economic analysis.
2. According to the tasks, hydro-energy conditions, or load status and planning objectives of the power station in the system, preliminarily determine the installed capacity of the power station and calculate corresponding electric energy indexes.
3. Attach reservoir stage-area-volume curve diagram (table)

## **Chapter 5 General layout and main structures of project**

1. According to the project scale, determine the design flood standard and preliminarily establish the earthquake fortification criterion.
2. Preliminarily select the project sites (dam site, gate site and plant site).
3. Preliminarily determine the general layout of the project according to site conditions and development modes of the power station.
4. Preliminarily determine basic layout, structural type, control elevation and main dimensions of the main structures.
5. Attach drawings and tables to include:
  - a) General layout plan of the project;
  - b) Plans and sections of the main structures;
  - c) List of major work quantities.

## **Chapter 6 Electromechanical equipment and hydromechanical structures**

1. Preliminarily determine the turbine type and unit capacity, select corresponding main and auxiliary equipment, draw up the layout plan and put forward preliminary calculation results of unit regulation guarantees, according to the installed capacity, unit operation mode, traffic conditions, equipment costs and other factors.
2. Preliminarily determine the power supply voltage level, main electrical connections, main electrical equipment, monitoring and protection mode and layout of the main electrical equipment.
3. Preliminarily determine types, parameters and layout of all kinds of gates, trash racks, valves and hoist equipment.

4. Attach drawings and tables to include:

- a) Main electromechanical equipment layout plan;
- b) Main electrical wiring diagram;
- c) Summary of work quantities of the main hydraulic machinery and equipment for the electrical and hydromechanical structures.

## **Chapter 7 Engineering construction**

1. Construction conditions are briefly described, and the construction diversion scheme, main project construction scheme, construction layout and construction progress are preliminarily determined.

2. Attach drawings and tables to include:

- a) External traffic schematic diagram;
- b) Construction progress chart (table));
- c) Major quantity summary sheet.

## **Chapter 8 Social and environmental impact assessment**

1. The natural social and economic status of the project area, and its affected areas, is briefly described and the social and environmental baseline is evaluated.

2. Impacts of the project on society and the environment, including impacts on society, the water environment, ecological environment, atmospheric environment and acoustic environment are predicted.

3. Social and environmental protection countermeasures are preliminarily determined.

4. Investment in social and environmental protection measures are estimated.

## **Chapter 9 Project investment estimation**

1. The compiling principle, basis and year of price level of investment estimation are briefly described; the main basic unit price and the unit price of main works are analysed and determined; the total project investment and static total investment are estimated.

2. Attach tables to include:

- a) Table of total project investment estimate;
- b) Table of estimate of auxiliary works;
- c) Table of estimate of construction works;
- d) Table of estimate of electromechanical equipment and installation;
- e) Table of estimate of hydro mechanical structure equipment and installation;
- f) Table of independent cost estimate.

## **Chapter 10 Economic appraisal**

1. Policies of the power industry and taxation in the country are briefly described.
2. Preliminary evaluation of the cost-effectiveness of the project.
3. Preliminary financial evaluation of the project.
4. Attach tables to include:
  - a) Economic benefit cost flow table;
  - b) Financial cash flow table.

## **Chapter 11 Conclusions and suggestions**

1. Conclusions on comprehensive evaluation of the project and suggestions on the work in the next stage are put forward.

## **Appendix B (Normative) Outline for feasibility study report**

### **Chapter 1 Comprehensive description**

1. Project geographical location, planning results for the river (section) where the project is to be located, pre-feasibility study results, approval opinions and compilation process of this document are briefly described.
2. Feasibility study results, comprehensive description and conclusions from the feasibility study stage are given.
3. Attach drawings and tables to include:
  - a) Project feature table;
  - b) Schematic map of river basin and project location;
  - c) General project layout plan and sections of main structures;
  - d) Geographical connection diagram of the power system connecting to the hydropower station;
  - e) General construction layout plan;
  - f) Map of reservoir inundated area;
  - g) General table of design estimates.

### **Chapter 2 Investment environment and project background**

1. Relevant policies on industries, enterprises, taxation and investment in the country, as well as the role that non-governmental organizations can play in the SHP industry, are collected.
2. Project background information is provided.
3. Information about the project sponsor is given.

### **Chapter 3 Hydrology analysis**

1. The physical geography of the river basin, basin and river characteristics, distribution and observation of meteorological (hydrological) observation stations, and the regional meteorological characteristics are briefly described.
2. Re-check results of runoff, flood, sediment, evaporation and ice regime are proposed.
3. Re-check results of the design section stage-discharge relation are proposed.
4. Attach tables to include:
  - a) Statistics of hydrological characteristic values over the years from the reference stations on which the design is based;
  - b) Annual (monthly) runoff and rainfall series;
  - c) Daily average flow series;

- d) Rainstorm volume and flood peak volume series;
  - e) Typical flood and design flood hydrograph table;
  - f) Table of main section stage-discharge relation curve outcomes.
5. Attach drawings to include:
- a) Watershed system and hydrological network distribution diagram;
  - b) Interpolation charts for runoff, flood, and rainstorm;
  - c) Annual rainfall and annual runoff frequency curve;
  - d) Daily average flow duration curve;
  - e) Storm and flood peak volume frequency curves;
  - f) Typical flood and design flood hydrograph table;
  - g) Main design section stage-discharge relation table.

## Chapter 4 Engineering geology

1. The main conclusions and review opinions of engineering geological investigations at the pre-feasibility study stage are described.
2. The overview of supplementary geological investigation work at this stage and all survey workload up to date are briefly described.
3. Conclusions of basic geological conditions, regional tectonic stability and seismic parameters in the project area are described.
4. Engineering geological conditions, reservoir leakage, immersion and reservoir bank stability in the reservoir area are described and the relevant treatment suggestions are put forward.
5. Engineering geological conditions of structures are described, engineering geological problems of the structures are evaluated, physical and mechanical parameters and hydrogeological parameters of the main rock and soil mass of the structures are determined.
6. Types, quantities and quality of various natural construction materials for the project are described and the investigation results at this stage are put forward.
7. General conclusions and suggestions are put forward.
8. Attach drawings and tables to include:
  - a) Comprehensive geological map of reservoir area;
  - b) Engineering geological maps of dam site and other structures area;
  - c) Geological map of bed rocks (including contour map of bed rocks) of the dam;
  - d) Engineering geological profile of the dam site and other structures area;
  - e) Seepage profile of the dam anti-seepage lines;
  - f) Distribution chart of natural construction materials production places;
  - g) Engineering geological profile of any specific areas of potential problems;

- h) Typical borehole histogram;
- i) Summary of test results of rock, soil and water.

## **Chapter 5 Water energy and project scale**

1. Water power calculation results and approval opinions at the previous stages are briefly described.
2. The hydropower output and related energy indexes of the project site are analysed and re-checked.
3. Project scales, including selection of normal storage water level and dead water level, runoff regulation calculation, installed capacity selection, unit rated water head and unit capacity selection, are re-checked; design values of ground motion parameters and corresponding seismic design intensity are re-checked.
4. Analyse reservoir operation, including determination of reservoir operation mode, reservoir sediment deposition analysis, sediment parameters, backwater calculation.
5. Attach drawings to include:
  - a) General project layout;
  - b) Reservoir stage-area-storage curve;
  - c) Curve of guaranteed rate of power generation;
  - d) Reservoir sedimentation longitudinal section and backwater curve;
  - e) Reservoir operation and dispatching graph.

## **Chapter 6 Project layout and structures**

1. The design flood standard is re-checked, and technical standards and main design allowable values on which the design is based are described.
2. The general layout scheme of the project is further compared and determined, based on pre-feasibility study results.
3. The type, quantity, layout scheme and main dimensions of the structures are determined and structural calculation and stability analysis are performed.
4. The project permanent traffic plan, building structure and comprehensive utilization plan are determined.
5. Project safety monitoring items and layouts are determined.
6. Attach drawings and tables to include:
  - a) Site layout plan;
  - b) Layout comparison and profile of main structure types;
  - c) General project layout plan and main structure arrangement plan and section of recommended scheme;
  - d) Project safety monitoring layout plan;
  - e) Results of stability and stress calculation for major structures;
  - f) Work quantity summary sheet.

## Chapter 7 Electromechanical, hydro mechanical structure, ventilation and heating

1. Basic parameters, such as turbine type, quantity and unit capacity, are selected; the turbine type and installation elevation are selected; and the form, quantity and arrangement of the auxiliary equipment and system of the turbine are selected.
2. The calculation for regulation guarantee of the unit is re-checked.
3. For a hydropower station with high sediment concentration in flow passing through the turbine, the anti-corrosion measures for major flow passage components are determined.
4. The voltage level, the number of transmission lines, and the connection point and distance of the lines and the power system are determined.
5. The main electric connection scheme, station service system scheme and the form, specifications, quantity and layout of electrical equipment are selected; monitoring, relay protection, excitation, operation control power supply, communication and other design schemes are determined.
6. The type, quantity, technical parameters, dimensions and layout of hydro mechanical structure gates, trashracks, valves and hoisting equipment are selected; corrosion, clogging and freezing prevention schemes and measures for hydro mechanical structures are selected.
7. The heating, ventilation and air conditioning scheme, and equipment form, quantity and layout are selected; firefighting design scheme, power distribution design and firefighting equipment layout are selected.
8. Attach drawings and tables to include:
  - a) Layout plan of electromechanical equipment in the main and auxiliary powerhouses;
  - b) Comprehensive characteristic curve of the turbine operation;
  - c) Chart of oil, air, water, and hydraulic monitoring systems in the hydropower station;
  - d) Geographical connection diagram of the power system connecting to the hydropower station;
  - e) Main electrical wiring diagram;
  - f) Auxiliary power and dam area power supply system diagram;
  - g) Monitoring and communication system structure and layout diagram;
  - h) General layout of hydro mechanical structure equipment of the project;
  - i) Short circuit current calculation results table;
  - j) Summary sheet of hydraulic machinery equipment;
  - k) Summary sheet of electrical equipment;
  - l) Hydro mechanical structure equipment summary sheet;
  - m) Summary sheet of heating, ventilation and air conditioning equipment;
  - n) Firefighting and automatic fire alarm equipment list.

## **Chapter 8 Construction organization design**

1. Construction conditions, including natural conditions, water supply, power supply, communication, traffic, material organization and on-site access are briefly described.
2. The natural material borrow area is selected, and mining, processing and transportation schemes are preliminarily determined.
3. The construction diversion and closure scheme, construction scheme of main works, layout of construction workshops, construction transportation, construction overall layout and general construction progress are determined.
4. Attach drawings and tables to include:
  - a) General construction layout plan;
  - b) Construction diversion procedures and project layout plans at each phase;
  - c) Diversion works structure chart;
  - d) General construction schedule;
  - e) Construction plant facilities, scale of production and quantity list of major machinery and equipment.

## **Chapter 9 Environmental protection design**

1. The natural social and economic status of the project area and it's affected areas is briefly described and the environmental baseline is evaluated.
2. Environmental assessment criteria are briefly described.
3. Project impacts on society and environment, including inundation, migration, water environment, water ecology, terrestrial ecology, atmospheric environment, and noise impact, are predicted.
4. The general situation of land acquisition and resettlement are briefly described, and the impacts on the living standards, infrastructure, community reconstruction, religious or ethnic customs, cultural relics, landscape and other aspects of resettled residents are analysed.
5. Social and environmental protection measures and countermeasures are put forward; environmental protection facilities and social impact compensation measures are designed; environmental monitoring programmes and social and environmental protection budget estimates are put forward.
6. Attach drawings to include:
  - a) General layout of environmental protection design;
  - b) Design plans for various environmental protection measures;
  - c) Layout of environmental monitoring points.

## **Chapter 10 Project cost estimation**

1. The project cost estimate includes compilation instructions, principles and basis, and a summary of estimate results.
2. Attach tables to include:
  - a) Estimate table;

- b) Construction project estimate table;
- c) Estimate table for electromechanical equipment and installation;
- d) Estimate table for hydro mechanical structure equipment and installation;
- e) Estimate of temporary construction works;
- f) Project unit price summary sheet;
- g) Material estimate summary sheet.

## **Chapter 11 Economic appraisal**

1. Project cost-effectiveness is evaluated.
2. Project financial appraisal is carried out.
3. The financing plan, financial analysis conclusion and economic analysis conclusion are described.
4. Attach drawings and tables to include:
  - a) Construction investment estimate table;
  - b) Total investment utilization plan and financing table;
  - c) Total cost estimate table;
  - d) Profit and profit distribution table;
  - e) Cash flow statement of financial plan;
  - f) Cash flow statement for project investment;
  - g) Schedule for repayment of capital with interest;
  - h) Project break-even analysis chart;
  - i) Project sensitivity analysis chart.

## **Chapter 12 Conclusions and suggestions**

1. Concluding opinions of the feasibility study report are summarized, the main differences between concluding opinions and the approval opinions in the pre-feasibility study stage are explained, and suggestions for future work are put forward.







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