Technology Tools Use for Mini Hydro Power Plant

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Abstract-The software tools for planning and designing small hydropower (SHP) facilities are reviewed and compared in this study. The focus is on computer tools and techniques for small-scale hydropower resource evaluation for the building of SHP plants at the preliminary or prefeasibility study level. The study provides a quick assessment of both historical and contemporary software tools utilized in the small hydro business. The techniques examined range from basic first estimations to very complex algorithms. The integration of assessment tools into Geographic Information System (GIS) settings has resulted in a significant improvement in the evaluation of the power potential of water streams in the event of spatial variability of various elements impacting their power potential force of stream. Several nations have reassessed their hydropower capacity using geographical data from their water stream catchments, creating and implementing technologies for automated hydro-site identification. On the Internet, GIS-based tools, known as Atlases, of small-scale hydropower resources. However, a true assessment of real SHP site viability necessitates some "on the ground" surveying, which may be significantly aided by GIS approaches that take into account the geographic heterogeneity of catchment features.

Keywords: Small hydropower (SHP); GIS; software tools for SHP assessment.

I. Introduction

The expense of evaluating SHP sites for development accounts for a sizable percentage of the entire project budget. To complete this evaluation correctly, a high degree of knowledge and skill is necessary. A number of computer-based evaluation tools have been created to solve this challenge over the last several decades, allowing a prospective developer to conduct an early assessment of a project's economic feasibility before investing large quantities of money. These tools range in complexity from basic initial estimations to complex programmes. However, a fair assessment of genuine, commercially viable potential necessitates some "on-the-ground" examination of potential sites and their feasibility.Potential for electricity generation As a result, Geographic Information System (GIS) software was developed.has shown to be quite useful in terms of gathering the wide variety of data necessary. This document goes into further detail on what is necessary. These technologies may be used to record geographical catchment information for a potential SHP site in a GIS database and utilise it to make choices about whether or not to build SHP plants. This study examines publicly available software tools and interactive maps/atlases that show the locations of SHP sites as well as their key characteristics. The primary objective of these tools is to identify possible SHP locations and assess their energy output and environmental impact. Before starting with a feasibility assessment, compatibility with environmental factors is a critical problem for the construction of a SHP site. This article is based on the knowledge and experience of nations with a high level of hydropower development, where specialised hydro software tools are widely used for planning and developing SHP facilities, starting with a preliminary resource or site evaluation and ending with a feasibility analysis. Only publicly accessible software assessment tools for SHP site creation are given, which can be obtained in the literature and include well defined computer methods. Obviously, this is for business use.

The particular algorithms in software are usually commercially sensitive, yet in other situations, they are the most important factor.

It's possible that certain functionalities will be made available to the general public. A comprehensive overview of the computer-based assessment tools used a decade ago for predicting the energy output of a particular small hydro scheme is given in [1]. The International Smal Hydro Atlas also presents valuable information on SHP assessment tools and methodologies used all over the world [2]. The major goal of these software tools is to develop a quick and accurate way to forecast the energy production of a certain hydro system. These forecasts entail determining the "head" and flow duration statistics that properly reflect the temporal variability of water output size of the plants' capacity. The first of these objectives is a straightforward physical measurement, as well as basic hydraulic loss calculations involving pipe materials, water velocities, and other factors. The second is far more challenging for SHP site inspection, and it is this that we will focus on the most difficult aspect of the problem is to solve. Long-term river flow data make it easy to estimate natural stream water energy; but, short-term flow records are more difficult to analyse, and ungauged locations are much more difficult. It goes without saying that hydrological analysis accuracy is critical.important for a hydro scheme's cost efficiency [3].

A GIS research was conducted to assess the quantity and size of prospective micro-hydro projects within a sample county in the United States to better understand the hydro resources accessible at the regional and local scales [4]. Property layers were added to a GIS-based map of the county.Ownership and borders, elevation, stream locations, and federal and state protected areas are just a few of the factors to consider. The stream power was computed using a standard formula utilising a basin-specific GIS programmer, Stream Stats [5], which is capable of estimating estimates of streamflow at ungauged locations and estimated elevation change.

A programme combined with GIS and remote sensing data (satellite pictures) was used to build a digital elevation model (DEM) and include river flow data for a preliminary hydropower site evaluation GIS techniques were used to find potential SHP locations [6], resulting in a map with an index that included hydrologic, demographic, economic, and other aspects. Later, in other countries, a preliminary evaluation of the micro- and macro-hydro power potential was carried out. calculating real energy using computerised maps of river basins and runoff [7].

In India, the hydropower potential of a mountainous stream basin was assessed using the spatial tool GIS and a hydrological model [8]. Prospective SHP development locations in this nation were identified using remote sensing data (satellite photos) [9]. The use of a Geographic Information System (GIS) on the site technical considerations in the choosing of a modest run-of-river hydropower project economic, environmental, and social impact factors were also used [10].

In Sri Lanka, a user-friendly GIS was created and implemented to efficiently produce, store, modify, analyse, and present information important to the identification, research, design, monitoring, and control of proposed and current mini-hydropower plant operations [11]. In South Korea, there is a GIS-based technique was presented for identifying potential SHP locations based on geographical characteristics [12]

The primary goal of this research was to evaluate publicly accessible software tools and interactive Web-based maps for SHP site identification, with assessments ranging from reconnaissance through pre-feasibility studies.

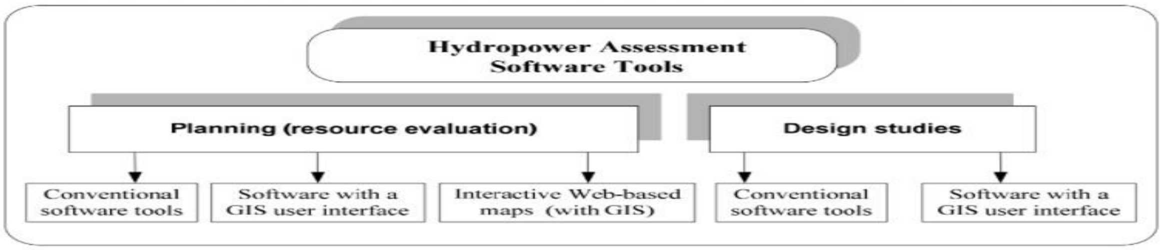
II. METHODOLOGY

Small-scale hydropower resources or potential, which are required for planning and building SHP facilities, are the subject of this research. Computational Fluid Dynamics (CFD) and various civil, geotechnical, and other computer applications for modelling hydromechanical equipment (for example, turbines) hydroelectric engineering that is relevantProject cost problems, such as comprehensive design studies, are outside the scope of this article and will not be covered.
There has been no distinction made between SHP resources and SHP plants based on any component. In most cases, a virtual size restriction for small hydropower plants is set. Their capacity, which is generally defined by installed capacity, ranges from a few kilowatts to 50 megawatts [14].

Reconnaissance resource studies, or the initial stage of SHP planning, are carried out to identify possible energy sources and estimate the amount of energy available in streams, and are not necessarily site specific. In the past, contour maps and standard computer programmes were commonly utilised to do this initial hydropower evaluation. The capacity and energy production of the stream were calculated using the available head and the mean annual flow or flow duration curve (FDC). Common approaches were used to determine these hydrologic parameters. GIS-based tools and other GIS-integrated solutions help this traditional technique, which has become more precise, easy, and fast.

Real-world hydropower projects are carried out using design software, which includes prefeasibility and feasibility studies before a final design is created or construction begins. Hydrologic data analysis, supported by specialised hydrologic software, calculates the flow available for energy production and is a critical initial step in assessing the feasibility of a hydroelectric project.

Figure 1. Software tools used for hydropower assessment.



III. RESULTS AND DISCUSSION

1.Software Tools For MINI-HYDRO Power Plant

SHP assessment software can be incorporated or not into GIS (i.e., using the spatial data of a catchment). Only the most recent computer-based programmes include GIS tools, or vice versa—some of them are GIS components (Figure 1). There are two primary ways to assessing river flow: the flow duration curve (FDC) and the simulated streamflow (model) methods. The mean annual flow (MAF) is a less accurate intermediate method that can be utilised in some applications. The software programmes used for hydropower research are listed in Table 1

Table 1. Overview of conventional software tools for SHP assessment.

Software Tools			Features				
Name	Developer	Applicable countries	Hydrology	Power and energy	Coasting	Economic evaluation	Preliminary design
Integrated method for power analysis (IMP) [27]	Natural Resources Canada and POWEL	International	Model	+	–	–	–
RETScreen® [29]	Natural Resources Canada	International	FDC	+	+	+	–
PEACH [31]	ISL Bureau d'Ingénieurs Conseils, France	International	FDC	+	+	+	+
Hydropower Evaluation Software (HES) [33]	Department of Energy, Idaho Engineering and Environmental Laboratory, USA	USA	MAF	–	–	–	–
SMART Mini Idro [18]	ERSE SpA, Italy	Italy	FDC	+	+	+	–
Hydrohelp [34]	Gordon J.L and OEL-HydroSys, Canada	International	FDC	+	+	+	–

Modified and updated from the International Small Hydro Atlas [2].

The majority of these software applications were created almost two decades ago, and some (such as RETScreen®) have been continually updated. Some programmes were considered promising at the time, but they never found a practical application. HydroHelp is a collection of applications that help hydro engineers create precise preliminary cost estimates for power plant sites by offering professional guidance throughout the design-cost process [17]. It has a six-turbine selection function to assist promoters and designers in selecting the best turbine for a certain site and market circumstances.

The integrated technique for power analysis (IMP) [15,16] is a useful tool for assessing small-scale hydroelectric power facilities. An experienced user can evaluate all aspects of an ungauged hydro site in about one day of in-house study using IMP (combined with the relevant meteorological and topographical data), which includes a power study, in about one day of in-house study using IMP (combined with the relevant meteorological and topographical data).

2. GIS Applications for Mini Hydropower Potential

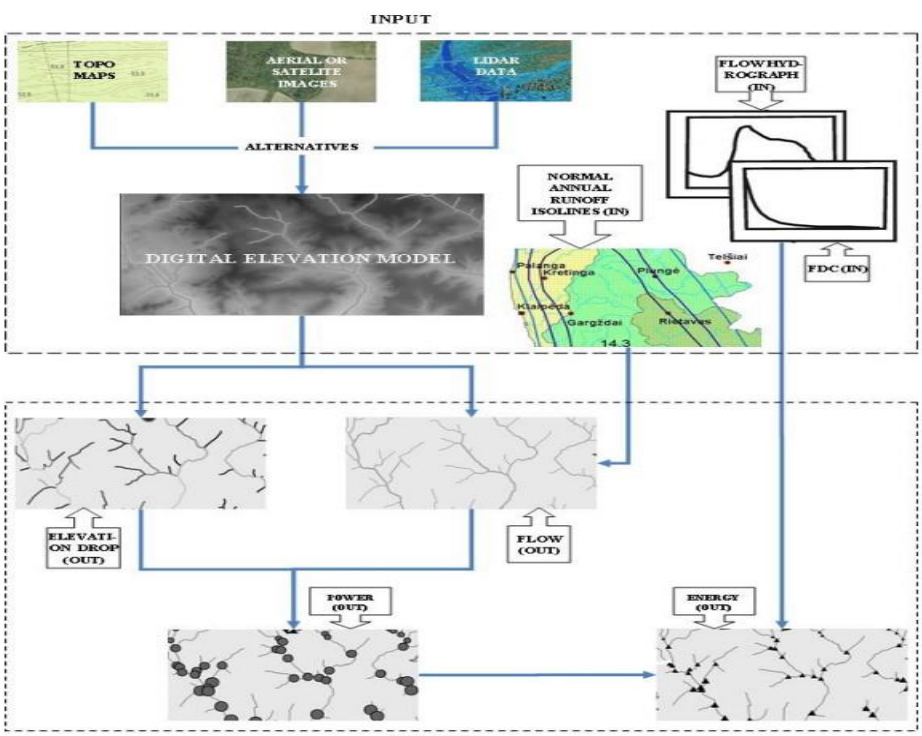
There are several different definitions for geographic information systems (GIS). They may be simply characterised as a system that integrates hardware, software, and data for recording, managing, analysing, and presenting all types of spatially linked information for the purposes of this article [18]. GIS allows users to examine, analyse, interpret, and visualise data in a variety of ways, including maps, globes, reports, and charts, to highlight correlations, patterns, and trends. A GIS may alternatively be defined as a collection of computer-based decision support tools for integrating geographical data from many sources, as well as for analysing, manipulating, and displaying such data. It is therefore a strong instrument for the administration of huge volumes of geographically distributed data in aquatic bodies, such as river basins, with all the advantages of computer capacity.

The first genuine GIS uses were land and forest surveys. GIS technology was then used to successfully visualise water resources and river networks. The development of GIS analysis tools was aided by the increasing collection of GIS-based data. Users of GIS from other fields may readily share and compare geographically referenced data, overlay different GIS layers, and gain new information.

The creation of DEM was a significant milestone in GIS history (Digital Elevation Model). They allow for the study of land formations and provide access to numerous hydrological and morphometric variables of a river basin in a relatively short amount of time. DEM data is derived from a variety of sources, including raw LIDAR (Light Detection and Ranging) data, historical topographical maps, satellite photos, and more. Each source necessitates various data processing technology and yields different results when considering DEM accuracy and data processing costs. By combining DEM with additional data layers (such as soil data, land use, and protected areas), more grounded and accurate hydropower planning estimates may be generated that take into account the current hydropower network. A general gastrointestinal examination

It is now too expensive to use LIDAR technology only for SHP projects, and it cannot compete with the usual practise of DEM production [13,19]. However, because this technology is employed in so many different practical sectors, the situation is fast changing (such as geodetic works, flood mapping, forests, and road development). The elevation decrease for each river reach may be simply calculated by overlaying a segmented river network over the DEM. Power and energy maps may be created by combining runoff time series, flow duration curves, and yearly flow data in GIS-based models.

Figure 2. GIS hydropower assessment tool. General model process flowchart.



The standard ArcGIS tools produced by ESRI (Environmental Systems Research Institute) are commonly utilised for analysing the application of GIS software for prospective evaluations. ArcGIS Spatial Analyst and ArcHydro [20], a recently created

ArcGIS extension that allows the user to select a number of hydrological parameters utilised by hydrologic models as input data, are particularly useful tools. Many hydrological models cannot be utilised as they are now without the use of GIS to prepare input data. Each hydrological model requires a large amount of non-GIS-prepared input data, making the use of GIS either impracticable or uneconomic. The quantity of needed input data for the hydrological model, a sub-basin separation method, and similar may be rapidly and efficiently computed using the DEM of the river basin, soils and land cover thematic layers, and the river network.

The same may be true for hydraulic models in 1D or 2D. A complete digital model of the surface for the river bed and its valley, including the constructed dams and the surface roughness distribution along the river bed, can only be produced using the right GIS tools [21].

The construction of a map with a geographical distribution of FDC characteristics is a unique GIS application. The FDC parameters collected at gauging stations are transferred to the attribute table of the new GIS layer and utilised for spatial analysis later. The values of these parameters can be estimated for ungauged river basins by using suitable methods for spatial interpolation.

3. Review of Case Studies for Mini Hydro Power Plant Assessment Based on GIS Tools
The advanced expertise of a number of nations in assessing hydropower resources and possible building locations using GIS technology is examined. Some countries have created interactive maps of these resources, which are available on websites and show site locations as well as key technical and economic parameters, allowing users to get the information they need quickly, while others do not display the data on the Internet or only provide it in limited quantities.

Table 2. Data sources for hydropower assessment [39].

Dataset Data Type	Accuracy	Source	Description
Canadian Digital Elevation Data	DEM/1:250K resolution	Geobase	Continuous representation of surface relief
Normal Annual Runoff Isolines	Vector/500 mm contour interval	LRDW	Normal annual depth of runoff
BC Watershed Atlas	Vector/based on 1:20K mapping	LRDW/Water Management Branch	Topographic reference for mapped hydrologic features
HYDAT Data 2005	Tabular	Water Survey Canada (WSC)	Daily flow data recorded and archived by WSC for all of Canada.
Hydrologic Zones	Vector/1:2M	LRDW	29 regions of hydrologically similar areas in BC

IV. CONCLUDING REMARKS

Table 3 shows the main characteristics of GIS integrated software for preliminary SHP site evaluation. The examination of traditional hydro software tools for a preliminary SHP site assessment reveals that they have progressed significantly over the last 15 years and can now account for a complicated river basin evaluation. Integration of these software tools into the GIS environment, as well as the penetration of GIS to the Web and the introduction of remote sensing methods, were all major milestones in SHP assessment.

In general, there are a few common components to consider when using GIS to estimate hydropower potential:
• Collecting hydrological parameters of river basins and related attribute data as spatial GIS data and applying them for broad-based analysis;
• Creation of a DEM for the river basin utilising a range of primary sources as input data for the construction of a GIS database and subsequent use in the assessment of hydropower potential;
• Creating SHP assessment tools as specialised GIS extensions and integrating them into GIS systems;

• Conducting SHP evaluations and presenting the findings using GIS tools, as well as their interactive usage on the Internet
Not all of the procedures described above in the instances studied were discovered in a study of GIS applications in precedent international cases, but certain components were always accessible. Hydropower software developers seldom design their own GIS tools, preferring instead to use standard ones or those produced by others. For example, the GIS programme StreamStats can calculate streamflow estimates for ungauged locations [7]. The DEM does not need to be produced in nations with more modern technology because it has already been developed for the entire country. GIS databases of the hydrographic network, protected areas, soils, and other regions have also been established in several nations. It is conceivable to identify the nations that have implemented modern weather and water quality monitoring systems that automatically transfer data from monitoring sites to GIS databases and are accessible through the Internet among the examples not listed. The needed resources for assessing SHP potential using GIS technologies in different nations are considerably variable.

Table 3. GIS-based Small Hydropower Atlases on the Internet.

SHP Atlas on the Internet				Features						
Name	Developer	Applicable countries	Accessibility	Hydrology	Power and energy	Possible SHP sites	Economic evaluation	Proximity information	SHP renovation	Accounting for other water uses, minimum flow releases
NVE Atlas. Potential for SHP plants [47]	Norwegian Water Resources and Energy Directorate (NVE)	Norway	Open access, interactive Web-based maps	MAF	+	+	+	+	−	−
Virtual Hydropower Prospector (VHP) [5]	Idaho National Laboratory	US	Open access, interactive Web-based maps	MAF	+	+	+	+	+	−
RHAM [40]	Kerr Wood Leidal Associates Ltd (KWL)	British Columbia, Canada	Open access, interactive Web-based maps	MAF/ FDC	+	+	+	+	−	+
Hydrobot [50]	Nick Forrest Associates Ltd. *et al.*	Scotland	Limited access	FDC	+	+	+	+	−	+
VAPIDRO ASTE [18]	ERSE SpA,	Italy	Open access, interactive Web-based maps	MAF	+	+	+	+	−	+

MAF: Mean annual flow; FDC: Flow duration curve.

GIS is frequently utilised in most suggested hydropower evaluation systems to show findings in the form of digital maps, which is highly handy for users. The user may also conduct a limited number of GIS functions with such maps (queries, etc.). Complex hydrological modelling may be done before putting the data into the GIS database, and only the simulation results are then transmitted to the database. The creation of the VAPIDRO-ASTE tool [18] is one example. Some modules are immediately incorporated into the GIS environment, while others run independently, doing the necessary computations and integrating the results into the GIS environment.

Before entering the data into the GIS database, complex hydrological modelling may be done, and only the simulation results are sent to the database. One example is the development of the VAPIDRO-ASTE tool [18]. Some modules are integrated into the GIS environment right away, while others operate in the background, doing the necessary calculations and integrating the results into the GIS environment

V. CONCLUSIONS

• Hydropower evaluation techniques based on computer software have significantly advanced during the last 15 years, allowing for the complicated integration of river catchment characteristics in particular. The introduction of geospatial information systems has largely contributed to this advancement (GIS).
• Recent advancements in GIS technology, as well as improved availability of high-quality topographic and hydrologic data, have made it feasible to estimate power potential on a large scale while preserving a high degree of detail. GIS data is generally available for free in most countries.

• For hydropower project assessments, remote sensing (e.g., LIDAR), which is becoming more cost efficient than traditional surveying, has marked a significant advancement in the production of digital elevation models, particularly in difficult-to-access locations.
• Using DEM and regional hydrologic data, these software tools are able to determine the amount of electricity available on all streams in a study area, filtering out locations inside ecologically sensitive or excluded regions, and to estimate project costs.
• While it is undeniable that a reliable evaluation of real SHP site viability necessitates some "on the ground" surveying, this traditional assessment may be considerably aided by computer programmes if the GIS approach incorporating the spatial variability of catchment parameters is included.

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