Low head hydropower – its design and economic potential

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Abstract: The large scale model of a Free Stream Energy Converter (FSEC) is built, and can be installed in protected as well as in tidal areas. This is one of the determined objectives of the EU-Project HYLOW, funded by the FP7. First field tests with rope winch and towing boat were done; further, in a protected area near Rostock, and the installation in the River Ems under tidal conditions and ship traffic, are planned for the first half of 2011. Besides, the permanent design control for the FSEC is as necessary as the monitoring of the behaviour of the model positioned in all the sites. If design changes or modifications are necessary, these can be done directly on site, respectively in the Steel Construction Company nearby. Whether it is suited for practice, however, is still dependent on other factors. The investigations are primarily limited on technical and ecological level. It is now necessary to look at the cost-sided development, too. Starting with considerations for the financing and economic efficiencies about expressive cost-benefit analyses up to design and material costs, the European need should be determined in hydropower for low potentials. Realization of hydropower plans takes a long period.

Keywords: *Low head differences, Free Stream Energy Converter, EU-Project, Hylow, Cost-benefit analysis.*

1. Introduction

One reason for the Hylow project is the rising demand for energy. Another one is the necessity to implement renewable energies, because of undeniable importance in view of declining natural resources. Small hydropower is a possible substitute for fossil fuels which are already limited. The European committee has fixed specific targets with a view to initiating change towards renewable energy. In order to achieve these objectives, energy generating systems, which were economically unattractive, are given greater priority.

The Hylow project focuses on the development of a mobile energy converter for low head differences – a topic which is usually neglected, because of missing significant results.

2. Motivation for hydropower

Compared to wind power and photovoltaic, small hydropower is often undervalued - at least in the public perception. In theory the worldwide demand for energy could be covered by hydropower. But it will not be economically practical, because of the uneven distribution of water resources on world territory.

2.1. Strong arguments

The power source “hydropower” offers many advantages.

Minimal emissions occur just in the installation period and in the first running period, when converters have to be stabled. A running energy converter does not need a great number of additional materials or energy. In sum there are low CO_2 emissions during operating time.

Hydropower requires no primary energy – therewith the respective countries relieve their own energy bills as well as they increase the security of energy supply. Furthermore, hydropower depends neither on the natural rhythm of the sun nor on the strength of the wind. This allows a permanent and continuous electricity generation.

There is a significant potential for hydropower in the EU and worldwide. However, the availability of use is limited by specific features of energy supply, such as localization, use of sites, power supply and current collection.

2.2. Background of Hylow

Small hydropower plants are close to nature; their design is often environmentally compatible. This applies to Hylow also. The floating Large Scale Model (LSM) of the FSEC is nearly 7,800 mm in length, 2,400 mm in width, and 3,500 mm in height. The wheel diameter is 3,200 mm and 1,100 mm in width (see Figure 1).

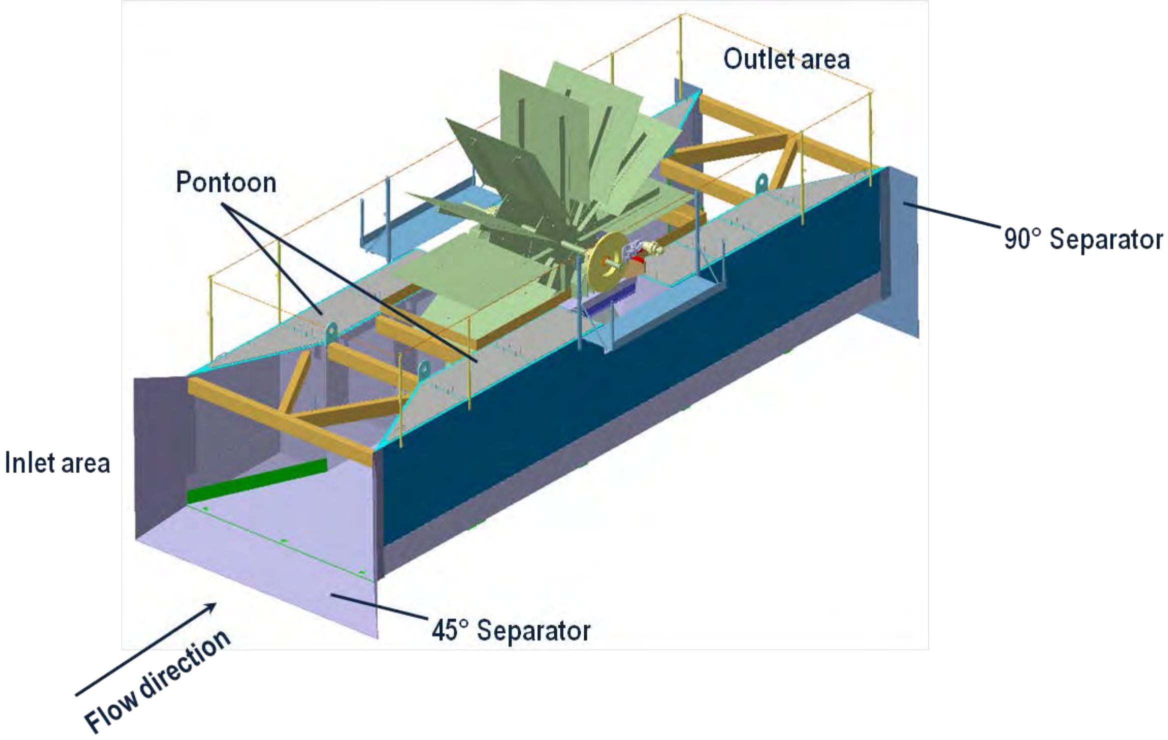

Fig. 1. The CAD model of the LSM, separators included.

The LSM will be placed in running waters with flow velocities of up to 1.5 m/s. The model is dimensioned for exceptional situations, in which the velocity rises, such as floodwaters or strong winds. To realize test runs with the LSM in protected areas no lubricants or other persistent products will be used. The power take-off is envisaged as a friction-type brake, and works without any liquids, so that even in the average case the environment takes no damage. For later applications and for deployment in developing countries to energy production, the brake system will be substituted with a generator solution which is adapted in ecological respects. [1]

3. Product development

Essential for product development activities, besides the idea, are calculations. These start with the power output to be expected. In addition, all forces, which appear, are to be taken into consideration.

3.1. Free Stream Energy Converter

The first geometry of the pontoon was given by calculations and basis tests done with simplified and down scaled configurations. The outline geometry consists of two hulls which are connected via a base. The hulls in the inlet area are v-shaped, so that the channel will get narrowed, and the flow velocity accelerates. This procedure corresponds to the Venturi principle. [1]

Fig. 2. The LSM on the first deployment – the naval base in Rostock.

During the whole project three field tests with the LSM at different locations (with expected flow velocities between 0.4 and 1.5 m/s) are planned. The first deployment site was envisaged for towing tests; these tests have been successfully completed in autumn, 2010 (see Figure 2). The second and third test sites are in a protected area near Rostock, and in the River Ems in Northern Germany.

Initial towing tests were meant to demonstrate the model behaviour during operational conditions. In addition, the floating behaviour of the model with different velocities and geometries (additional separators) should be tested. The LSM delivered an electric power output up to 500 W.

The towing tests show that something has to be changed concerning the geometry of the LSM. The best results in the first deployment site were achieved with separators at both ends of the LSM. In the inlet area works the separator as a scoop with an angle of 45°, and in the outlet it has 90°. In order to limit the costs several models have to be analysed with the computational fluid dynamics (CFD) software FLOW-3D [3]. See first results in Figure 3.

The FLOW-3D tests are useful for the fine adjustment of length, arrangement and angular size of the separators. Moreover, the trim angle of the FSEC can be adjusted according to the waterline (horizontal alignment in the flow). Figure 3 shows three situations in FLOW-3D with different arrangements of the separators. The set velocity is determined with 1 m/s, and it changes as expected in several areas of the flow pattern – in narrowed parts of the channel are higher velocities than in the widened areas. The simulations are ongoing; final results are expected in spring, 2011.

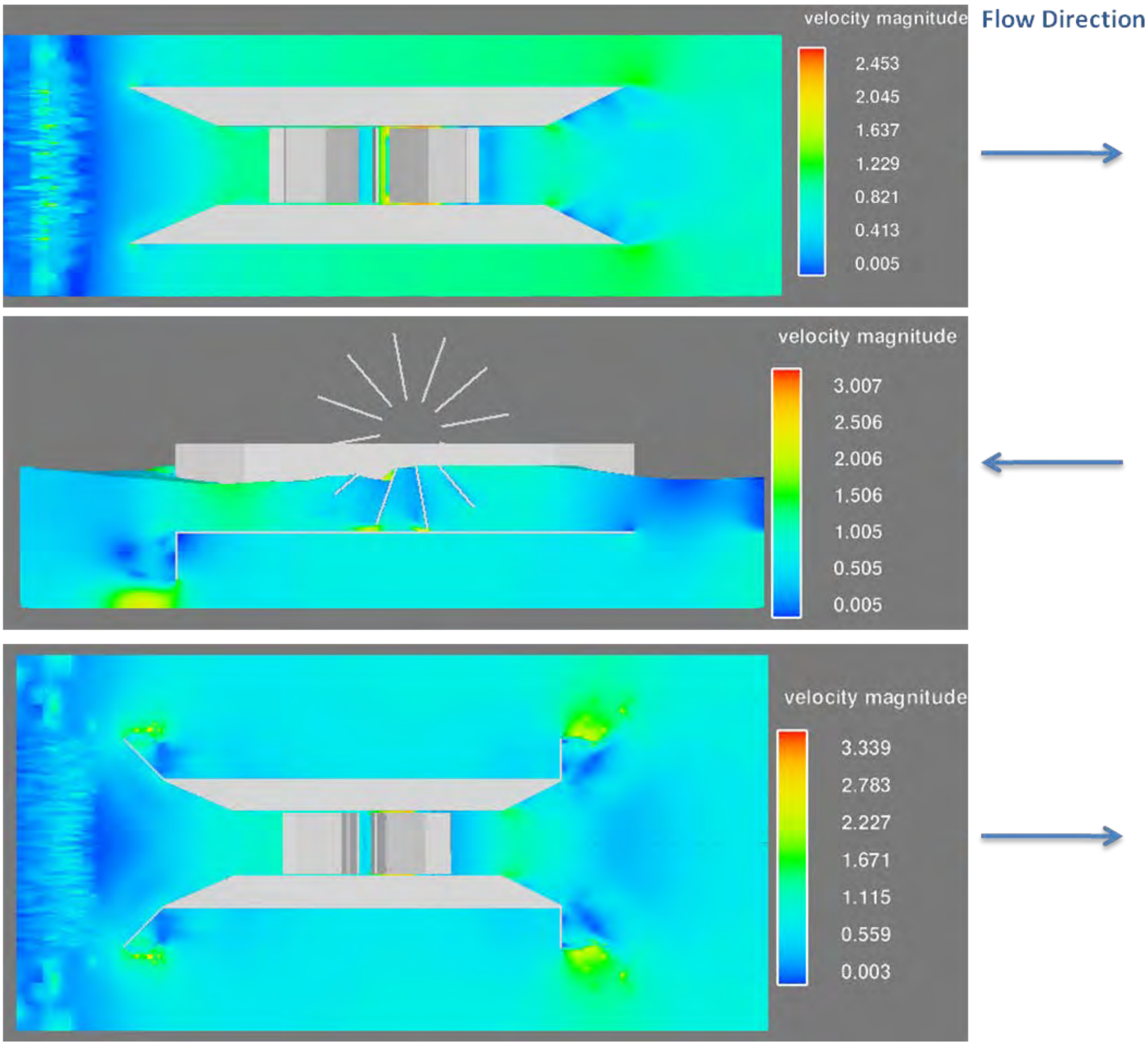

Fig. 3. Geometry tests with FLOW-3D.

3.2. Cost report of the FSEC prototype

To check the efficiency of the FSEC the annual costs are compared with the benefit. The benefit will be calculated from the sale of electricity to the energy companies. Thus, the investment can determine the annual profit, as the difference between the yields and costs. For the considerations, the average values of all costs and yields are used.

The total costs of the energy converter arise from different cost types. A calculation basis of these are the given production costs of the prototype which consist as follows (table 1):

Table 1. Production costs for prototype.

Cost type	**Total** [€]
Personnel costs	30,491.00
Material, standard parts & consumables	24,750.00
Indirect costs (20 % of direct costs)	11,048.20
Manufacturing costs	66,289.20

In these costs no costs for research and development included. Because of the prototype, no values of experience have still integrated into the production procedure. Moreover, detailed values of wear behaviour are neglected, because there are no empirical values for this special case exist.

4. An FSEC in Europe – where conditions are most favorable

The benefit of the FSEC consists in the production of electrical energy using the potential of flowing water. For the feed in existing electrical grids there are fixed feed-in tariffs which mostly have a limited duration. In addition, a purchase obligation by the energy groups exists in several European countries.

4.1. Feed-in tariffs

Table 2 shows height and duration of the feed-in tariffs for selected European countries. To calculate the annual yield the payment must be multiplied by the energy generated in the year. It is assumed that the FSEC works continually without interruption 8,760 hours per year. The electrical energy is the product of the expected average electric power (assumption = 3 kW) and the annual power consumption in hours.

In case of permanent consumption the electrical energy for 3 kW power output will be 26,280 kWh. The resulting annual yields are given in the right column of table 2 [3]. The countries are sorted according to the amount of feed-in tariffs, starting with the highest.

Table 2. Feed-in tariffs and their time limits in Europe.

European country	Amount of feed-in tariff	Duration of feed-in tariff*	Annual yield
	[€/kWh]	[years]	[€]
Great Britain	0.23	-	6044.40
Italy	0.22	15	5781.60
Germany	0.1267	20	3329.68
Netherlands	0.125	15	3285.00
Latvia	0.11	10	2890.80
Slovenia	0.105	15	2759.40
Czechia	0.081	30	2128.68
Denmark	0.0803	10	2110.28
Luxembourg	0.079	15	2076.12
Spain	0.077	25	2023.56
Portugal	0.075	20	1971.00
Ireland	0.072	15	1892.16
Greece	0.07	10	1839.60
Lithuania	0.07	-	1839.60
Slovakia	0.066	15	1734.48
France	0.06	20	1576.80
Estonia	0.051	12	1340.28
Belgium	0.05	-	1314.00
Bulgaria	0.045	15	1182.60
Austria	0.0378	13	993.38
Hungary	0.029	payoff time	762.12

* Some values are not known; duration is unlimited.

The European countries of the first rows have a good chance to invest in the small hydropower market. Therefore the use of the energy converter is determined as a value size. Now as a comparison the costs are considered.

4.2. Overview to cost covering

Thus, the production costs fall with renewed individual manufacture on 70%, because the development is concluded and is possible for a shorter manufacturing time by experience-guided, structured work.

With a small batch production of five energy converters, a cost reduction on 60% (according to the manufacturer) is to be achieved. With these estimates the manufacturing costs change as follows (table 3):

Table 3. Types of production series.

Manufacturing costs for	**Price per unit** [€]
Prototype	66,289.20
Individual production	46,402.44
Batch production (5 pieces)	39,773.52

It is assumed that steady wear behaviour during utilisation exists. The amount of annual depreciation may be calculated according to the linear method. Thereby in every period the same depreciations are created. If the lifespan is 20 years, than the following results can be represented (table 4):

Table 4. Cost structure for all considered production series.

	Prototype 100%	**Individual production 70%**	**Small batch production 60%**
	[€]	[€]	[€]
Personnel costs	30,491.00		
Direct costs	24,750.00		
Indirect costs	11,048.20		
Total manufacturing costs*	***66,289.20***	***46,402.44***	***39,773.52***
Imputed depreciations**	3,314.46	2,320,12	1,988.68
Imputed interests***	1,756.66	1,229.66	1,054.00
Imputed costs of capital	***5,071.12***	***3,549.78***	***3,042.68***
Leasing costs	200.00	200.00	200.00
Maintenance costs	253.56	177.49	152.13
Insurance, taxes, administration	530.31	371.22	318.19
Annual costs	***6,054.99***	***4,298.49***	***3,713.00***

* Total manufacturing costs = A_0
** A_0 / lifespan
*** A_0 / 2 * 5.3% (discount rate of German Central Bank) [4]

The imputed costs of capital are divided into imputed depreciation and imputed interests. The imputed depreciations are the costs for losses in value. Whereas the imputed interests are the interests due on the amount of money lent over the maturity of the operation period.
The amount of the leasing costs depends on the plant size and the location. It varies from country to country, therefore it was assumed that the leasing costs are 200 € per year (average value in Germany). The maintenance costs are 5% of the imputed costs of the capital. The costs for insurance, taxes and administration are 0.8% of the total manufacturing costs.

Concluding, the following table 5 gives an overview to the first five European countries and the profit per annum (annual yield minus costs).

Table 5. Profit per annum for all considered production series.

European country	**Prototype 100%**	**Individual production**	**Small batch production**
	[€]	[€]	[€]
Great Britain	-10.59	1,745.91	2,331.40
Italy	-273.39	1,483.11	2,068.60
Germany	-2,725.31	-968.81	-383.32
Netherlands	-2,769.99	-1,013.49	-428.00
Latvia	-3,164.19	-1,407.69	-822.20

The profit table clearly shows that the prototype is not profitable in the next 20 years. With the other production forms the FSEC under described conditions could be a lucrative business.

5. Summary

The FSEC is able to convert the kinetic energy of flowing waters into electricity. By means of low head differences and by applications of separators power outputs of at least 3 kW are expected. To attain this objective a lot of additional research is needed. Initial results of the ongoing FLOW-3D trials show how the design of the FSEC might essentially change.

The presented cost report demonstrates that only in a few European countries the balance between annual costs and benefit can be achieved. The most important criterion is how long the payback period is. The other item to note is that all the assumptions are defined as cases with ideal conditions. It is still uncertain how long an FSEC in this form will work.

In the manufacture of the FSEC prototype, personnel and material costs is the biggest cost block by far. As a result of batch production and growing experience the personnel costs will be reduced. It is to think about moving the production of further plants in countries which have lower production costs to cover the risk of rising material costs, because of the development in the steel market. It is expected that the steel price and in this connection the material costs for the converter will increase. The saving in materials has direct impacts on the operating earnings, especially when using alternative materials such as wood or glass fibre plastics (GRP) [2].

Acknowledgements

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On the Large Scale Assessment of Small Hydroelectric Potential: Application to the Province of New Brunswick (Canada)

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Abstract: The mapping of the small hydropower (SHP) resource over a given territory is indispensable to identify suitable sites for the development of SHP renewable energy projects. In this study, a straightforward method to map the SHP potential over a large territory is presented. The methodology uses a synthetic hydro network (SHN) created from digital elevation models (DEM) to ensure precise hydro head estimations. From the SHN, hydro heads are calculated by subtracting the minimum from the maximum elevation of synthetic stream segments. Subsequently, stream segments with low hydro heads over a specified maximum distance are removed. Finally, the method uses regional regression models to estimate the annual baseflow for all drainage areas in the study area. The technical SHP potential can then be estimated as a function of the hydro head and maximum penstock length. An application of the method is made to the province of New Brunswick, Canada, where SHP maps have been developed to promote the development of the SHP energy sector in the province. In terms of the SHP opportunity, it is shown that the province of New Brunswick (71,450 km^2) has a good SHP resource. Using a representative hydro head (10 m) and penstock length (3,000 m) for the region, 696 potential sites have been identified over the territory. Results show that the technical SHP potential for New Brunswick is 368 MW for the conventional hydroelectric reservoir SHP configuration.

Keywords: *Small hydropower (SHP), Resource assessment, Hydroelectric power potential, Mapping*

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1. Introduction

The definition of small hydropower (SHP) varies according to jurisdictions; in some instances, hydroelectric generating stations having installed capacities of up to 15 MW are generally characterized as SHP [1], while in Canada, hydroelectric generating facilities with installed capacities of up to 50 MW are considered as SHP [2]. Similarly to other renewable energy sources, such as wind power, the mapping of the SHP resource over a given territory is indispensable to identify suitable sites for the development of SHP renewable energy projects.

Large scale SHP assessments for pre-feasibility studies have been done in the United States [3], where data from hydrological regions were used to estimate the annual average streamflow for ungauged drainage areas; the estimated annual average streamflow was then used in conjunction with digital elevation models (DEM) to determine the hydropower potential for sites situated in ungauged natural streams in the corresponding regions. In Canada, even though the province of British Columbia is the only province to have developed an official map of the SHP resource [4], many Canadian SHP sites have been mapped in the International Small-Hydro Atlas [5]. However, the latter was developed with information from ref. [6-10] which are generally based on a combination of historical data and observations from field research; modern mapping techniques have only been implemented in a few of these studies.

In this paper, a methodology for the large scale assessment of small hydroelectric potential is presented along with an application to the province of New Brunswick, Canada. In the first instance, a method is described to find the available hydro head on the hydrographic network of a study area. Secondly, the annual streamflow is calculated, as a function of the hydro head and maximum penstock length, for each available hydro head sites. The technical hydropower potential is then calculated and the study results are presented in the form of a SHP map.

2. Hydropower Potential Modeling

At a given site, the hydropower potential, P, can be calculated as

$$P = \rho Q g h \eta \tag{1}$$

where ρ is the density of water (kg/m^3), Q is the volumetric fluid flow rate (m^3/s), g is the gravity constant (9.81 m/s^2), h is the height (m) of the drop (gross hydro head), and η is the efficiency coefficient. In this study, the density of water is assumed constant at 1,000 kg/m^3, the efficiency coefficient is set to 0.8 while the hydro head is defined as the height difference between the intake and the generating station. Thus, with these assumptions, only two remaining parameters, Q and h, are needed to determine the hydropower potential for any site in a given study area. A third indirect parameter, the penstock length, can also be used in the determination of the gross hydro head.

2.1. Hydro head modeling

Assuming that a drainage area generates enough streamflow to be considered as a potential site, the first phase of large scale SHP mapping is to locate every potential hydro head on all stream segments of the hydrographic network. To this end, a synthetic hydro network (SHN) using DEM is created to ensure relatively precise hydro head estimations. This is done because spatial entities in the National Hydro Network (NHN) are based on existing data of different agencies [11] and do not perfectly match with the DEM. Since the SHN perfectly matches the DEM, the interoperability between information layers is assured. GIS software tools such as the TauDem tools [12], along with algorithms based on the previous works [13-15] are used to create the SHN from the DEM. The SHN is then validated with the NHN and all stream segments present in the SHN that does not correspond to a NHN stream segment are excluded. From the SHN, hydro heads are calculated by subtracting the minimum from the maximum elevation of the synthetic stream segment. Subsequently, because the penstock length represents an important capital cost of the total civil work costs for SHP projects, a limit is imposed on the Euclidian distance between the highest and lowest node of a SHN stream segment, which is used to represent the penstock length. In this work, the maximum penstock length is established at 3,000 m and all stream segments up to the maximum penstock length having hydro heads of less than 10 m are removed from the model, due to the altitudinal precision of the DEM (± 5 m, 90 % of the time).

2.2. Streamflow modeling

A regional regression model based on the work of Vogel et al. [16] is used to estimate the annual streamflow for all drainage areas in the study area, namely:

$$Q = e^{C_0} X_1^{C_1} X_2^{C_2} \ldots X_n^{C_n} e^{\varepsilon} \tag{2}$$

where Q is the observed annual streamflow or baseflow in a gauged basin (m^3/s), X_i are the various drainage area characteristics (climatic and physical attributes such as average annual temperature, average annual precipitation, elevation and drainage area), C_i are the ordinary least square regression coefficients and ε is the residual of the model.

In order to evaluate the efficiency of the regional regression model between the estimation results and the observation data, a goodness of fit statistical model, known as the Nash and Sutcliff efficiency index [17], E, is used and is given by:

$$E = 1 - \left[\sum_{t=1}^{T} \left(Q_0^t - Q_m^t \right)^2 / \sum_{t=1}^{T} \left(Q_0^t - \overline{Q_0} \right)^2 \right] \tag{3}$$

where Q_o is the observed streamflow at a given time t and Q_m the modeled streamflow. The Nash and Sutcliff efficiency index ranges from -∞ to 1, where 1 represents a perfect match between the model results and the observed data.

2.3. A case study: Province of New Brunswick, Canada

As an application of the methodology proposed, and in order to promote the development of the small hydropower energy sector in the province, the large scale SHP assessment methodology for the conventional hydroelectric reservoir SHP configurations is applied to the province of New Brunswick (NB), Canada. The province of New Brunswick, one of the smallest of the Canadian provinces, both in size (71,450 km^2) and population (748,319), is part of the Maritime provinces on the eastern coast of Canada. The topography of New Brunswick consists in three major geographic regions. The north-west region is characterized by the Appalachian Mountains, which are dominated by Mount Carleton (820 m above sea level). The center of the province is composed of small rounded hills delineated by river valleys. Finally, the southern part of New Brunswick is composed of small hills sloping down to the Bay of Fundy, with the exception of the south-eastern part of the province which is composed of the Caledonia Highlands. In terms of climate, the province of New Brunswick is located within the Atlantic Ecozone, which is characterized by a continental climate due to eastward moving air masses. Although the moist climate provides an annual runoff varying from 600 to 1,000 mm, the annual runoff is more important in the southern region of the province, near the Bay of Fundy, due to higher precipitation events. The province's hydrographic network is composed of three major rivers: the St. John River, which drains the western part of New Brunswick, takes its source in the state of Maine, U.S.A. and discharges into the Bay of Fundy; the Restigouche River, which discharges into the Baie des Chaleurs, drains the northern part of New Brunswick; finally, the Miramichi River, which drains the eastern part of New Brunswick, discharges into the Gulf of Saint Lawrence.

2.3.1. Hydro head modeling input data

The DEM's used to generate the SHN are retrieved from the Canadian Digital Elevation Data (CDED) [11]. The raster dataset, at a 1:50,000 scale, has a minimum cell resolution of 0.75 arc seconds, which represents approximately 32 m^2 for the province of New Brunswick. The altitudinal precision of the dataset is ±5 m, 90% of the time. Furthermore, because some watershed areas are contiguous to the state of Maine, DEM covering corresponding sections of the state are also used. The dataset used to cover the corresponding watersheds are taken from the National Elevation Dataset (NED) 1 Arc Second of the United States Geological Survey (USGS) [18]. The NED dataset has a resolution of approximately 30 m^2 and is resized to match the CDED resolution. Finally, due to computing limitations, the DEM for the entire region is divided into 9 sub-regions, as shown in Fig. 1. These sub-regions are defined by using aggregates of sub-sub-drainage areas as delimited by the Water Survey of Canada (WSC) dataset [19], thus maintaining the topology of the SHN within each sub-region.

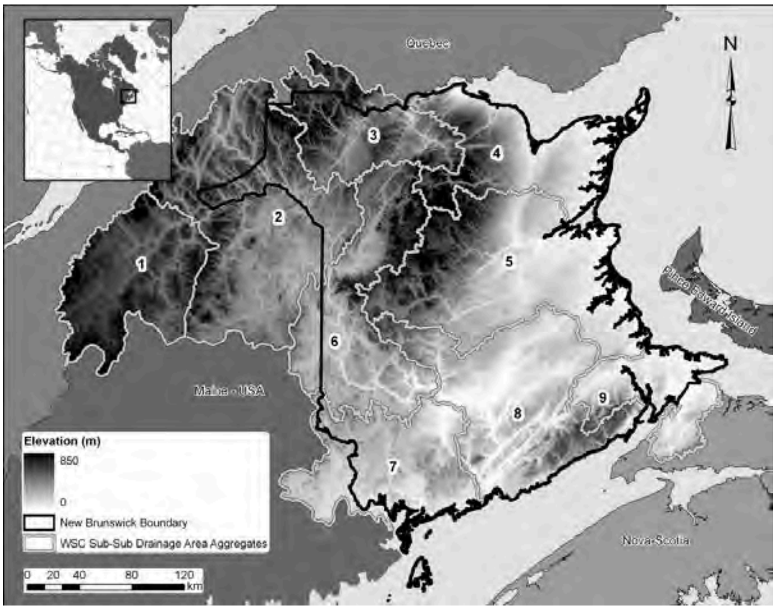

Fig. 1. Study area; sub-regions used for the extraction of the DEM.

2.3.2. Streamflow modeling input data

The climatic attributes such as average annual temperature and average annual precipitation used in several regional regression models tested in this study are taken from ref. [20-21]. In terms of the physical attributes used in the regional regression models, the majority of them, i.e. average slope, average elevation, elevation range, drainage area and eccentricity of the drainage area, are calculated from the DEM.

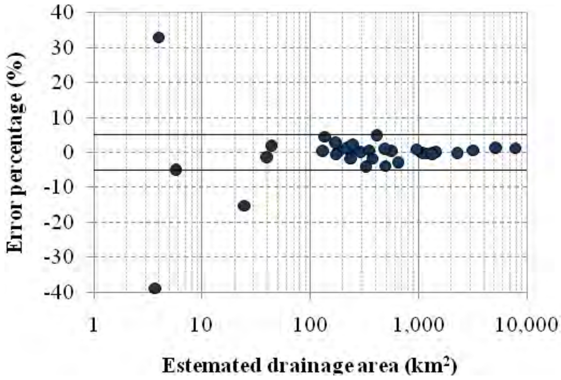

Fig. 2. Relative error between reference basin drainage areas and DEM-based basin drainage area estimation.

Previous research work in regional regression models has shown that the basin drainage areas provide good correlations in such models [16]. As is shown in Fig. 2, by comparing the DEM-based drainage area results for basins having hydrometric stations measuring natural flow to those of the Water Survey Canada as reference, it can be seen that the relative error decreases as the drainage area increases. In this work, a lower limit of 50 km^2 was imposed on drainage basins, such that hydro head having drainage areas with less than the lower limit where not considered. Finally, streamflow data from hydrometric stations [22], located across New Brunswick and having at least 30 years of continuous data, while being situated in basins with drainage areas larger than 50 km^2, are used in the various regional regression models tested.

3. Results

3.1. Hydro head modeling results

Results from the hydro head modeling showed that a total of 696 hydro heads in the province of New Brunswick satisfied the modeling constraints. In general, as in the case of other research in similar topography [23], because the topography is more variable in the upper part of a watershed area, stream segments with high hydro heads were generally located in the upper parts of a watershed area, while sites located in lower parts of a watershed area generally had lower hydro heads. Fig. 3 shows the distributions of hydro head sites by their characteristics.

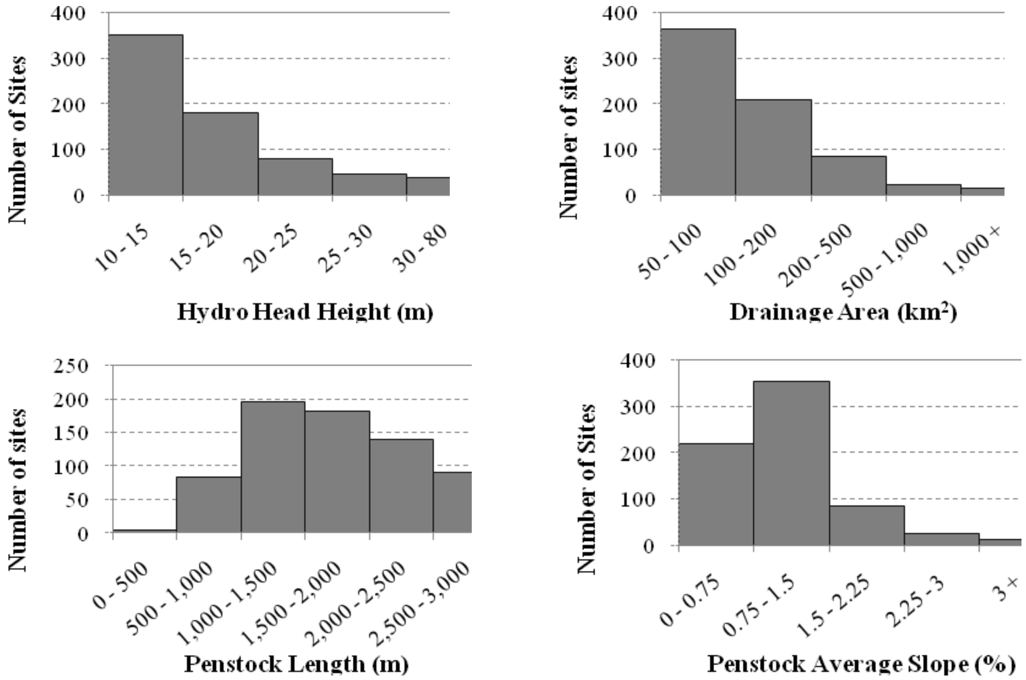

Fig. 3. Distribution of the hydro head sites.

3.2. Streamflow modeling results

In order to estimate the average annual streamflow for all basins in the study region, multiple regional regression models have been attempted in this work; the regional regression model having both the lowest average relative error (6.5%) and the highest Nash and Sutcliffe efficiency index (0.993) was chosen:

$$Q_m = e^{-16.552} A^{0.977} P^{1.733} D^{0.133} \tag{4}$$

where Q_m is the modeled streamflow (m^3/s), A is the drainage area (km^2), P is the average annual precipitation (mm) and D is the average elevation (m) of the drainage area.

3.3. Mapping results

While the methodology described in this paper can be used to estimate the SHP resource potential for both conventional hydroelectric reservoir and run-of-river SHP configurations, only results for the conventional hydroelectric reservoir SHP configuration are presented. Fig. 4 shows the mapping results of the SHP resource potential, for the conventional hydroelectric reservoir SHP configuration, in the province of New Brunswick. For this SHP configuration, the technical SHP potential for New Brunswick is 368 MW. The sites range in

SHP potential from 92 kW to 16.1 MW; the average potential for the 696 sites is 528 kW per site, while the median power potential is 303 kW.

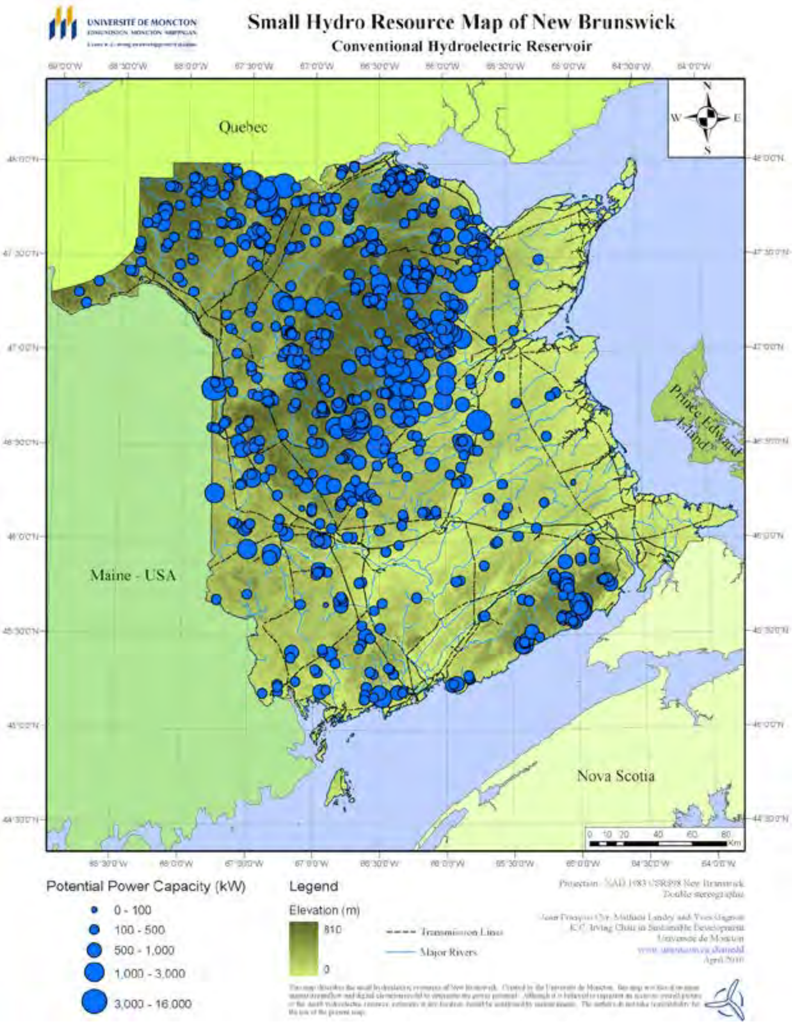

Fig. 4. SHP resource map of New Brunswick for conventional hydroelectric reservoirs.

4. Discussion and Conclusion

In this work, a straightforward method to map the small hydropower (SHP) potential over a large territory was presented. While the methodology presented in this paper is based on previous research work in this field of study, it contains several advantages which are not exclusive to this work but where their combination as a whole represents a significant advancement in this field. First, the methodology is general such that few variables are needed to perform a SHP study. Furthermore, the variables needed in the methodology are readily available at large scale for SHP studies in Canada or in other countries having publicly available GIS data. Secondly, the methodology can simultaneously evaluate and compare the SHP for both conventional and run-of-river configurations over a given area; this point represents a significant advancement in the field of study. Third, the methodology uses the gross hydro head, which significantly reduces the computational efforts of site selection. Fourth, the methodology is extremely fast and cost-effective when implemented using GIS-based software. However, the methodology introduces uncertainties in the estimation of the SHP resource potential which are due to the estimation of the efficiency of the SHP systems, the neglecting of SHP system head losses due to friction, and the use of yearly baseflow data instead of monthly baseflow data. Finally, field measurements of terrain could be used to increase the accuracy of potential site locations.

An application of the method was made to the province of New Brunswick, Canada, where SHP maps were developed to validate the methodology and to promote the development of the small hydropower energy sector in the province. In terms of the SHP opportunity, it was shown that the province of New Brunswick has a good SHP resource. In comparison to the neighbouring state of Maine[1], a previous study [24] identified that there were over 5,883 sites in the state of Maine having a technical SHP potential capacity of 2,780 MW, thus giving an average SHP of 472 kW/site. In New Brunswick, results from this study have shown that there is a technical SHP potential capacity of 368 MW distributed on 696 sites; thus giving an average SHP of 528 kW/site.

Future work should focus on the elimination of potential sites that are not sustainable economically, environmentally or socially. To this end, potential sites that are located within federal and provincial park boundaries should be notably excluded. In addition, drainage basins having issues such as water supply, tourism, sport fishing, and the presence of species at risk should also be eliminated from the model.

Finally, the New Brunswick SHP map results have shown that the province of New Brunswick has a good small hydropower (SHP) resource which should be developed not only for its environmental benefits and attributes, but also for the social and economic benefits of its residents.

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