Energiforsk

APPENDIX 1. PROGRAM DESCRIPTION

DESIGNATION

PROJECT NUMBER

VKH41000

Erik Isberg

Acting program manager

070 164 44 75

E-mail: erik.isberg@energiforsk.se

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Program for Hydrological Development in the Hydropower Industry, HUVA: Program period 2024–2026

The program for Hydrological Development within the Hydropower Industry, HUVA, plays an important role in providing hydrological insights necessary for the continued success of the hydropower industry amidst the energy transition. Its primary focus is to advance hydrological knowledge and develop new methodologies, particularly targeting hydrological forecasting, a crucial aspect for efficient water resource management in hydropower production. This has further implications for the estimation of long-term effects from environmental adaptation measures. No other forum focuses on the improvement of runoff forecasts with practical applications for the hydropower industry. Thus, HUVA constitutes an important and unique network in the field.

Background

In 1981, a working group called the HUVA group was established to support hydrological development within the hydropower industry. Over the years, activities have addressed operational issues within hydropower (e.g., hydrological forecasts and frazil ice issues), design flood estimation (e.g., extreme climatological and hydrological conditions), water availability and balance (e.g., climate change effects and method development for snow measurements), and actively contributed to knowledge dissemination through courses and conferences.

Significance of HUVA's work for the industry

The overall goal of HUVA is to increase the precision of runoff forecasts in the short and long term. This is not an end in itself; improved runoff models and forecasts lead to efficient utilization of hydropower resources and serve as the basis for trade-offs against other interests, such as environmental measures. Improvement of runoff forecasts occurs partly through the development of models and tools, and partly through improved input for model calibration and operation. Development occurs as technology evolves and new solutions emerge, in close collaboration between industry, SMHI (Swedish Meteorological and Hydrological Institute), and academia, resulting in valuable forums for cooperation. This has also contributed to a broad application of program results and the development of models and climate scenarios produced by, for example, SMHI. SMHI's HBV model was developed for the hydropower industry, and continuous development has occurred within the HUVA program.

The aim is to facilitate the operationalization and application of results from the program's research and development activities, for the hydropower industry. An important part of HUVA's work is therefore that funded initiatives are designed in a way to ensure that new tools and methods can be integrated and operationalized. This process is ongoing and with varying time horizons depending on the maturity of the tools being developed.

Goals and Benefits

Hydrological model calculations and forecasts are required to efficiently use hydropower resources. Reliable runoff forecasts are also important for dam safety and emergency preparations. The thematic areas monitored within the program are described in Table 1.

Table 1. Thematic areas that are monitored by HUVA, setting the tone for R&D activities funded by the program.

Effective management of water resources to support a sustainable energy system	Runoff forecasts are a prerequisite for optimized water management and efficient hydropower production. As the energy system changes, and intermittent energy production increases, the regulatory capacity of hydropower becomes increasingly important. This change also affects the production pattern of hydropower and water management over time. This will lead to even higher demands for runoff forecasts with high accuracy and further development of the models used.
Impact of climate change on hydrology	Questions regarding the impact of climate change on runoff are a significant aspect for the future of hydropower. In this regard, HUVA contributes to increased understanding of future flow regimes and how hydrological models and climate scenarios can be applied for planning and management of water resources.
Dam safety	Runoff forecasts have a significant impact on cooperation in a river regarding handling of high flows, which directly affects the maintainance of dam safety. Authorities have great confidence that the industry maintains the quality of runoff forecasts. Hydrological model calculations form the basis for design flood calculations. Onthis theme, it is important to have quality-assured input data and well-developed models so that investments in dams are made based on a robust basis.

A significant goal of the program period 2024–2026 is to investigate the need for improved methods and/or models for runoff calculations. In research, hydrological models based on machine learning are gaining terrain and commercial products are beginning to emerge. Leading questions that need to frame the R&D activities funded by the program are:

- How much further can the industry go with the models and tools used today?
- What other alternatives exist to find solutions to the development needs that exist?

Development needs prioritized for the program period 2024–2026

To pinpoint the most significant needs for industry-wide efforts, a workshop was held in 2023 with researchers and representatives from SMHI and researchers from Swedish and Norwegian universities. An analysis of needs has been carried out by members of the program's steering group in their respective companies and discussed at HUVA's strategy meetings. Today, the hydropower industry uses the HBV model operationally on a daily basis with input of daily aggregated precipitation and mean temperature. The model is set up and calibrated for relatively large catchment areas and used for three different purposes: calculation of historical or observed runoff, producing a short-term 10-day forecast, and a long-term statistical forecast (longer than 10 days). The catchment is represented by average values or point values. To adequately describe important hydrological processes, the model requires a higher resolution, both spatially and temporally. Another important aspect is the need for hydrological models to have the flexibility to modify their structure with relative ease. This allows for continuous and efficient model development, for example integrating and selecting among various descriptions of hydrological processes, such as different snow models with varying complexity.

During the program period 2021–2023, a distributed model was set up for the Ume River, among others, with higher spatial resolution. During the program period 2024–2026, the aim is to evaluate the potential of the distributed model compared to the existing operational model. This evaluation could be complemented by testing models based on artificial intelligence (see further below).

Three prioritized development themes and how the industry will benefit are described and summarized below.

1. *Hydrological model*

As the requirements for the role of hydropower in the energy system change, there is an increasing need for finer resolution in forecasts to control production in shorter time steps. Increased model resolution goes hand in hand with the need for high quality input data of the same resolution. Currently, it is possible to produce runoff forecasts with higher spatial and temporal resolution. However, before operational use, it is necessary to assess how forecasts at such resolutions compare in space and time with the current operational setup and investigate the prerequisites needed for operational implementation.

Shorter time steps: In spring, when daily temperature fluctuations are high, the daily mean temperature does not provide adequate information of the melting process. This means that the snowmelt process is often incorrectly represented by the hydrological model. The need for hydropower production varies greatly within the day, and planning is done for short time steps. A higher temporal resolution for temperature and precipitation could increase the possibilities to optimally manage the hydropower resource, for example, when runoff increases rapidly.

Spatial resolution: Currently, catchment areas used for modelling are often too large to describe hydrological processes well, or to capture local conditions. High spatial resolution improves opportunities to use measured data such as snow measurements. In recent years, HUVA has participated in several development projects for estimating the water content of the snowpack, which cannot be fully utilized with current model resolutions.

Correct information at the right time: Higher resolution corresponds to increased information, which can lead to difficulties in data interpretation, or make the work cumbersome. Different users within the companies have different needs. Developing flexible tools with the ability to choose what and how (e.g. resolution) to display data and model output is therefore a highly relevant aspect.

A flexible model structure: A model that is modularly structured would enable the adaption of different hydrological model algorithms as needed. For example, using an energy balance module to improve model calculations during the melting phase, or a snow module to implement snow measurement results.

Input and calibration data: The reliability of calculated runoff depends largely on the quality of the data used for model calibration and the data used for model operation. Currently, daily data is normally used. In recent years, SMHI's manual station network has steadily decreased. However, SMHI has begun to replace these with automatic measuring stations. This means that the availability of data with higher temporal resolution is increasing, which would benefit runoff calculations. The hydropower industry also contributes with meteorological and snow measurements to ensure present and future needs for reliable forecasts are met.

New models and methods may also require other data than what is currently collected.

2. *Hydrological forecast*

Short-term forecast: The uncertainty of the short forecast (up to 10 days) is largely determined by the uncertainty in the incoming meteorological forecast. Currently, these forecasts include an uncertainty interval, but no other related information is provided. Providing a description of forecast uncertainty can improve decision-making.

- How can the uncertainties of the forecast be quantified and/or described in a pedagogical manner? For example, by presenting probability indicators of the meteorological forecasts.

- Can the meteorological forecast be improved by giving SMHI access to real-time data from measuring stations owned by the industry?

Long-term forecast: The long-term forecast (more than 10 days) is based on historical data for precipitation and temperature. However, the effect of climate change raises the question of how relevant historical data continue to be.

- How should the effect of climate change be managed so historical data can continue to be relevant in long-term forecasts?

- The quality of meteorological seasonal forecasts is steadily increasing. How can meteorological seasonal forecasts contribute to improve runoff forecasts? For example, by capturing signals from large scale atmospheric circulation, of upcoming extreme events such as drought or heavy rainfall.

Impact of climate change: Climate change will affect runoff. However, how is uncertain. It is important for the industry to address this from several perspectives, which concerns both short- and long-term forecasts. A better understanding of long-term changes and the uncertainty in these estimates can contribute to better informed decision making for long-term production planning and investments.

- Climate scenarios currently used to describe possible future flows result in outcomes with a large spread. Is it possible to develop methods to better utilize scenarios with divergent outcomes, both for hydropower risk management and assessment of long-term capacity for production and flexibility?

- The impact of climate change on return periods of extreme events is an important issue to investigate further. The hydrological model performs better under average weather conditions, or the climate for which it was calibrated to. How will the model perform under extreme conditions?

3. The possibilities of increased digitalization

A common theme among the prioritised development needs is the possibility of increased digitalization and streamlining of the hydrological forecast chain. Currently, manual work is required, meaning that resources are not used efficiently, such as for input data correction or manual adjustment of runoff forecasts. Simultaneously, important processes or trends in the forecast chain are sometimes missed. There is therefore a need to further investigate possibilities for improving such processes. In recent years, methods using artificial intelligence (AI), primarily machine learning (ML), have gained ground, including in meteorological and hydrological applications. Significant development is now taking place in this area. However, the Swedish hydropower industry has lagged behind in the application of such methods. To catch up, there are significant development needs.

Artificial intelligence and machine learning:

We identify several potential areas of use, especially for efficiency in operational environments and decision-making, as there are high demands on turnaround time. For example, model correction, snow data assimilation, and development of new methods for hydrological forecasts can be optimized with ML.

Furthermore, ML could be used to quickly identify weaknesses in the hydrological models, especially when major forecast errors occur. Likewise, there is potential to increase performance in forecasting of extreme events, as models are currently often calibrated against average conditions. This is to improve the operational forecast both in terms of misses and turnaround time.

A more comprehensive application of ML methods should also be considered. For example, investigating to what extent ML can compete with current methods, especially in real-time. Comparison and sensitivity analyses are required for such an evaluation. Alternatively, investigating how ML can contribute with complementary decision support during hydropower production planning.

This is not an exhaustive list; other development opportunities not mentioned may also be of interest.

State of the art monitoring

An important aspect of HUVA is the collective knowledge and expertise within the group, along with the network of external contacts held by the members. Within the group, the ambition is to acquire knowledge and inspiration about hydrological development carried out by other actors, inside and outside Sweden. The group members monitor the above-described areas to be able to disseminate knowledge within and outside the group through literature studies, theme days, and conferences.

Budget

The proposed budget for this programme period is SEK 3,600,000 excluding VAT.

Table 1. Budget for the Hydrological Development Program, Program Period 2024–2026.

	(SEK excluding VAT)			
	2024	2025	2026	Total
1. R&D projects (external contractors)	880 000	880 000	880 000	2 640 000
2. Planning and coordination of HUVA course and HUVA day (Energiforsk)	100 000	100 000	100 000	300 000
3. Program management (Energiforsk)	220 000	220 000	220 000	660 000
Total	**1 200 000**	**1 200 000**	**1 200 000**	**3 600 000**