**Platforms or operational systems for forecasting or flood prevention**

**and their linked**

**hydrological or hydraulic models**

(Preliminary inventory)

Climate and Water Department

World Meteorological Organization

November, 2017

**INITIAL CONSIDERATIONS**

* This review corresponds to current platforms or operational systems intended to provide flood forecast that help National Services assess a potential flood event, to prevent or anticipate it.
* The majority of the models collected are open-source, apart from a few of them that provide open services for research and educational purposes (it is written in the point “Additional information”).
* The numerical modeling is generally composed of a set of models (hydrological, hydraulic), some include statistical techniques.
* The descriptions of the platforms, systems or models are collected from the official websites as well as from linked scientific papers.
* All online references were accessed for the last time on November 2017.

**INVENTORY OF PLATFORMS: FLOOD FORECASTING AND EARLY WARNING SYSTEMS**

**EUROPEAN FLOOD AWARENESS SYSTEM (EFAS)**

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| **Website:**https://www.efas.eu/ | **Developers:**European Commission  |
| **Download:**Not applicable | **Registration required:** |
| **Technical features:**This is an operational system monitoring and forecasting floods across Europe that provides flood early warning information up to 10 days in advance. EFAS regroup National and Regional Hydrological Services and the European Response and Coordination Centre (ERCC). This system is carried out under Copernicus emergency management service framework1. EFAS is focused on evaluating a potential flood event on European basins with sufficient time in order to take preventive measures in case of its occurrence. It provides information in real time about flood events that occur in continental scale and national scale. At national level, the EFAS forecasts could be taken up and adjusted according to the needs of theirs basins and using their local forecasting system. The EFAS flood modelling is based on GloFAS –global ensemble streamflow forecasting and flood early warning - which is composed of an integrated hydro-meteorological forecasting chain et a daily monitoring system. The hydrological modelling is done by a coupling of two model: LisFlood a model used to simulate river discharge for flow routing in the river network and groundwater mass balance, which is set up on global coverage to resolutions of 0.1° (~10 km) in space and daily time step for input/output data, and HTESSEL a land surface hydrological model that computes the land surface response to atmospheric forcing and estimate the water surface and energy fluxes, the temporal evolution of soil temperature, moisture content and snowpack conditions.EFAS use multiple weather forecasts as input but mainly those based on ECMWF (European Centre for Medium-Range Weather Forecast). |
| **Documentation (i.e. user’s manual, quick start guide) :**<http://www.copernicus.eu/main/emergency-management> |
| **User’s assistance:** |
| **Additional information:** Every national, regional or local authority involved in flood forecasting within its country can become an EFAS partner. EFAS forecasts are provided for free and are not limited to EU Member States. |

**POM (Plateforme opérationnelle pour la modélisations) - Vigicrues**

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| **Website:**<https://www.vigicrues.gouv.fr/> | **Developers:**SCHAPI – Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations |
| **Download:** | **Registration required:** |
| **Technical features:**The operational flood forecast network in France is based on the POM that can be visualized through Vigicrues site, which informs about the flood threat of rivers in real time. It is updated twice a day in order to facilitate prevention or evacuation measures in case of floods. During flood the information can be updated at any time.The national flood prevention network is integrated by several hydrometric units (28) that measure, adjust, record by telemetry and analyze water levels and flows and many flood forecasting service (19). As for the meteorological forecasting these are provided by Meteo-France, rainfall products are derived from radar observations with corrections of terrestrial data.The hydrological modeling is done using different models according to each watercourse, among the main models are: GJ4R and GRP – hydrological model, MASCARET 1D hydraulic model and TELEMAC 2D hydraulic model.SCHAPI have implemented an operational method to f to better identify intense rainfall and to anticipate flash flood in basins that are not equipped with gauge station by AIGA (Adaptation d’Information Géographique pour l’Alerte des crues). The principle of AIGA is to compare streamflow simulated from real-time radar rainfall with threshold values, in order to characterize a rain event. The radar rainfall information is provided over different duration (1h to 72h) by Météo-France. |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:** The current French operational flood forecast is based on experiences gained by regionals platform as SOPHIE, which integrates conceptual rainfall-runoff models and was used by the regional flood forecasting services to provide real-time forecasting and warning to the population. |

**DEWETRA**

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| **Website:**<http://www.cimafoundation.org/en/cima-foundation/dewetra/> | **Developers:**CIMA Research Foundation, Italian Department of Civil Protection |
| **Download:**Not applicable | **Registration required:**WMO can provide access |
| **Technical features:**DEWETRA is an integrated operational system designed to forecast, monitor and prevention climate-related risks. It was created by CIMA foundation to be operated by the National Department for Italian Civil Protection (who has access to the platform).This system or platform operates in real-time to collect different hydro-meteorological data that allow updating forecast models, analyze vulnerability areas and produce risk scenarios. Dewetra uses a software architecture that includes a Web-SIG interface to visualize the information such as real-time observations from automatic hydro-meteorological stations, weather radar and satellites. The streamflow forecasts are also added to the platform and the others models output to support decision-making concerning the issuing of warning messages.According to CIMA this platform is currently used by at national level by forecasters and disaster managing authorities in different countries: Bolivia, Lebanon, Albania and the Caribbean at the regional level. In terms of flood modeling this system uses the hydrological model FloodPROOFS (Probabilistic Flood Forecasting Operational System).  |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:**The Dewetra Platform is offered as an Open-Source tool to the WMO affiliated countries as an Italian contribution to the WMO programs on flood management and forecasting (FFI and APFM).  |

**DELFT-FEWSS flow forecasting system**

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| **Website:**<https://www.deltares.nl/en/software/flood-forecasting-system-delft-fews-2/> | **Developers:**Deltares - Dutch Institute for applied research in the field of water and subsurface |
| **Download:** | **Registration required:** |
| **Technical features:**Delft-FEWS is an operational platform developed for flood forecasting and warning system. It integrates real time data (rain, level, flow, temperature, etc), numerical weather predictions, radar data and climatological data to generate flood forecasting.In the numerical modeling this platform integrates different hydrologic and hydraulic models which may be different between the regions connected to the platform. Such are the case of: HEC-HMS, HEC-RAS, HEC-Res Sim, HBV, TOPKAPI, Sacramento |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:**[https://publicwiki.deltares.nl/display/FEWSDOC/Models+linked+to+Delft-Fews](https://publicwiki.deltares.nl/display/FEWSDOC/Models%2Blinked%2Bto%2BDelft-Fews)The information about several models linked to DELFT-FEWS is provided in the link above |

**Flood Forecasting Centre (FFC) for England and Wales**

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| **Website:**http://www.ffc-environment-agency.metoffice.gov.uk/ | **Developers:**FFC – England and Wales |
| **Download:** | **Registration required:** |
| **Technical features:**FFC is a specialized hydrometeorology service that forecast natural flooding like river, surface water, tidal/coastal and groundwater.Flow data is derived from G2G |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:** |

**GREEN KENUE**

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| **Website:**https://www.nrc-cnrc.gc.ca/eng/solutions/advisory/green\_kenue\_index.html | **Developers:**National Research Council Canada |
| **Download:** | **Registration required:** |
| **Technical features:**Green Kenue is an advanced data preparation, analysis, and visualization tool for hydrologic modelers to assist them with surface hydrological modeling, forecasting and event simulation. A user-friendly, state-of-the-art interface integrates environmental databases and geospatial data with numerical models and simulation data. Green Kenue is free to download and is currently used by more than 4000 users in more than 40 countries.Green Kenue provides complete pre- and post-processing for the WATFLOOD, Raven,UBC Watershed and HBV-EC hydrologic models. The models can be applied to simulate and forecast storm water runoffs, flooding, watershed flows and other hydrological surface events for design, emergency preparedness or other purposes. Unlike other GIS tools, Green Kenue adds a fourth dimension so that changes over 3D space and time can be easily viewed and analyzed. Lake level rises, climate change influence, flood inundation progression and recession, weather forecasts and hydrological predictions can all be represented and reported with fidelity using Green Kenue. |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:** |

**INVENTORY OF HYDROLOGICAL MODELS**

**LISFLOOD**

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| **Website:**<https://ec.europa.eu/commission/index_en>🡺 Lisflood | **Developers:**Joint Research Centre (JRC) of the European Commission (1997) |
| **Download:**  | **Registration required:** |
| **Technical features:**LisFlood is a hydrological rainfall-runoff model based on a raster grid, specifically developed to take advantage of high-resolution topographic data sets. This spatially distributed model includes two-dimensional channel routing model and the surface runoff is routed through each cell using finite-difference solution to solve the kinematic wave equations. Lisflood is being currently using by the EFAS for flood forecasting in whole Europe. These applications have employed grid cell of 100 meters for medium-sized catchment, to 5 km for modeling in Europe and 0.1° (10 km) for global modeling. Long-term water balance is simulated in daily time step and individual flood events in hourly time intervals, or even smaller. Meteorological forcing required are: Precipitation (mm/d), ET0-potential evapotranspiration rate (mm/d), EW0-Potential evapotranspiration rate from open water surface (mm/d), ES0-Potential evapotranspiration rate from bare soil surface (mm/d), Average daily temperature (C°). Main principles: Precipitation and Meteorological forcing from weather services satellite information, Infiltration is controlled by variable infiltration capacity (VIC), Soil water redistribution between 2 soil layer via Equilibrium method using van Genuchten hydraulic conductivity curves, Percolation to groundwater is based on (un)satured conductivity + Darcy equation. |
| **Documentation (i.e. user’s manual, quick start guide, tutorials):** |
| **User’s assistance:** |
| **Additional information:**This model is implemented in a raster GIS environment wrapped in a Python based interface. It can run in Windows and Linux environment.  |

**GR4J** (Génie Rural à 4 paramètres Journalier)

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| **Website:**<https://webgr.irstea.fr/en/modeles/journalier-gr4j-2/> | **Developers:**IRSTEA (Institut de recherche en sciences et technologies pour l’environnement et l’agriculture) |
| **Download:** | **Registration required:**No |
| **Technical features:**GR4J is a rainfall-runoff model designed to reproduce the overall hydrological behavior of a basin and it is principally based on the link between the precipitation and the evapotranspiration on the basin and its flows at the outlet.The structure of this empirical model is based on a set of interconnected reservoirs that empty and fill up over time translating rainfall into river flows. It operates on a daily time step and has 4 parameters, which have no direct physical meaning and are determined by a calibration phase. It requires a chronic flow observed ideally over 15 year.The four parameters to optimize during calibration:X1 : the production store maximal capacity (mm),X2 : the catchment water exchange coefficient (mm),X3 : the one-day maximal capacity of the routing reservoir (mm),X4 : the HU1 unit hydrograph time base (days).Since 2012, the snow accounting model CemaNeige is integrated for improving discharge forecasts in snow-influenced catchments. Several versions have been derived from GR4J due to its adaptations in many case that have included others parameters, time steps or spatial structure. There is an operational version named GRP that has been coupled with the Mascaret hydraulic model (which will be presented later) |
| **Documentation (i.e. user’s manual, quick start guide, tutorials):** |
| **User’s assistance:** |
| **Additional information:**The easy structure of this model has allowed to be implemented in codes like R, python. There are calibration and optimization routines available in Matlab.  |

**TELEMAC 2D**

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| **Website:**<http://www.opentelemac.org/index.php/presentation?id=17> | **Developers:**LNHE (Laboratoire National d’Hydraulique et Environnement) d’EDF  |
| **Download:** | **Registration required:** |
| **Technical features:**TELEMAC 2D is a model to simulate hydrodynamic problems fluvial and maritime from the resolution of Saint Venant equations, using the finite-element method and an interpolation of triangular elements, which means that it can be refined particularly in areas of special interest. It can simulate the propagation of floods and can be coupled with other models to complete its application.This model requires a series of information such as: spatial data of flood zones (geometries of watercourses, bathymetry), hydrological data (flood hydrographs...) and other data of flood areas (drainage network, infrastructure...). The principal outputs from TELEMAC 2D are the spatio-temporal variations of water levels and the water velocities.TELEMAC 2D is designed to evolved and allows the user to modify the basin applications. This hydraulic simulation tool has been adapted to the flood forecasting chain in France from precipitation forecasting.  |
| **Documentation (i.e. user’s manual, quick start guide, tutorials):** |
| **User’s assistance:** |
| **Additional information:**The set of TELEMAC 2D routines to each calculation code are written in Fortran-90 and could be modified according to the specifications of users. |

**MASCARET**

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| **Website:** | **Developers:**LNHE (Laboratoire National d’Hydraulique et Environnement) d’EDF |
| **Download:** | **Registration required:** |
| **Technical features:**MASCARET is a software for hydraulic modeling that regroups all one-dimensional calculation codes for flows with free surface of the LNHE and is based on the Saint-Venant equations.  It allows modeling a wide range of possibilities in branched or meshed networks for both fluvial and trans-critical flows, in steady or non-permanent state. This model covers a wide range of studies including flood propagation and modeling of lateral flooding. MASCARET is used by SCHAPI to forecast water levels and flows on different monitored tributaries of the hydraulic network.  The information requires by this model is the similar to that used by TELEMAC 2D. There is a version that integrates these two models, which is an open-source software called Telemac-Mascaret.  |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:**The calculation codes are written in Fortran 90. Mascaret as Telemac 2D has a powerful and user-friendly graphical interface for modeling hydraulic networks and  both are integrated to numerous data pre-processing and post-processing tools. |

**FLOODPROFS**

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| **Website:**<http://www.cimafoundation.org/en/cima-foundation/seawetra/> | **Developers:**CIMA foundation |
| **Download:** | **Registration required:** |
| **Technical features:**FloodPROOFS model provide an estimate of the probability of excess of critical levels in the key sections of the basins. It uses both the available meteorological observations and the quantitative forecast to compute the river discharge encompassing the snow melting and the effects of waterworks (dams, weirs,etc)This model integrate observed meteorological data (temperature, rainfall, solar radiation, wind speed and relative humidity) and satellite data (from: MODIS, Meteosat) to assess the extension of the snowpack and the soil saturation. Besides the forecast of the river discharge, FloodPROOFS also offers a daily set of analysis of the current saturation level of the soil and of the main characteristics of the actual snow cover. |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:** |

**GRID to GRID (G2G)**

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| **Website:**<https://www.ceh.ac.uk/services/flood-modelling> | **Developers:**Centre for Ecology and Hydrology (CEH), UK |
| **Download:** | **Registration required:** |
| **Technical features:**G2G (Grid-to-Grid) model is a physical-conceptual distributed hydrological model that represents the spatial variability in the catchment. It integrates rainfall forcing spatially distributed derived from networks of raingauges and/or radars.The model is configured for FFC to run at a timestep of 15 min on a 1 km grid. Spatial datasets of terrain, soil/geology and land-cover are used to support its configuration and parametrization. The principals inputs required for G2G are gridded values of rainfall and potential evaporation. It includes a water routing component based on a kinematic wave formulation. |
| **Documentation (i.e. user’s manual, quick start guide) :** |
| **User’s assistance:** |
| **Additional information:** |

**HBV**

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| **Website:**<http://www.smhi.se/en/services/professional-services/energy/hbv-state-of-the-art-hydrological-modelling-1.7540> | **Developers:**Swedish Meteorological and Hydrological Institute (SMHI). |
| **Download:**Under request | **Registration required:**Not applicable |
| **Technical features:**The model is a standard forecasting tool in Sweden and other Nordic countries, and also used for simulations in ungaugedcatchments, mainly in small and unregulated rivers. Forecasting for the Swedish hydropower companies are made in approximately 100 catchments. In addition operational or scientific applications of the HBV-model are known from more than 50 countries around the world.The HBV model is today an Integrated Hydrological Modelling system: a modern, well-tested and operational tool. It can be linked with Real Time Weather Information and Forecast Systems. It can be installed either on stand-alone PCs, in a client server concept, or integrated with other systems.HBV includes the following applications:* Hydropower short term inflow forecasts for operational hydropower planning at dispatch centers and volume forecasts of up to a year for seasonal reservoir planning.
* Dam safety: design flood computations including reservoir management strategies.
* Climate change: studies of the effect of changing climate conditions on run-off patterns, soil moisture, ground water recharge and evapotranspiration.
* Flood warnings: stream flow and volume forecasting for appraisal of flood risks and development of flood risk maps.
* Pre-feasibility studies: quality control of water stage and discharge records, extension of historical records and ground water simulations.
* Water supply: soil moisture simulations, water balance mapping for water demand planning, drought studies and water availability assessments.
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| **Documentation (i.e. user’s manual, quick start guide, tutorials):** |
| **User’s assistance:** |
| **Additional information:**HBV is not an open source model but there are non-commercial users Licenses for research purposes at universities or research institutions.  |

**HEC-HMS**

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| **Website:**<http://www.hec.usace.army.mil/software/hec-hms/> | **Developers:**Hydrologic Engineer Center, U.S. Army Corps of Engineers |
| **Download:**<http://www.hec.usace.army.mil/software/hec-hms/downloads.aspx> | **Registration required:**Yes |
| **Technical features:**The Hydrologic Modelling System (HEC-HMS) is a fully-featured multiple purpose surface hydrology and river modelling system that performs flood forecasting. It includes simulation components for all segments of the hydrologic cycle. Precipitation can be modelled with grids (radar) or observation gauges, and snowmelt can be included if required. Infiltration can be modelled for single storm events or continuously. Overland runoff can be modelled with a unit hydrograph, kinematic wave, or conceptual semi-distributed grid cells. Flood wave routing can be performed with Muskingum, modified Puls, kinematic wave, or Muskingum-Cunge variable parameter.HEC-HMS is designed to simulate the complete hydrologic processes of dendritic watershed systems. The software includes many traditional hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing. HEC-HMS also includes procedures necessary for continuous simulation including evapo-transpiration, snowmelt, and soil moisture accounting. Advanced capabilities are also provided for gridded runoff simulation using the linear quasi-distributed runoff transform (ModClark). Supplemental analysis tools are provided for model optimization, forecasting streamflow, depth-area reduction, assessing model uncertainty, erosion and sediment transport, and water quality.The software features a completely integrated work environment including a database, data entry utilities, computation engine, and results reporting tools. A graphical user interface allows the user seamless movement between the different parts of the software. Simulation results are stored in HEC-DSS (Data Storage System) and can be used in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation.  |
| **Documentation (i.e. user’s manual, quick start guide, tutorials):**<http://www.hec.usace.army.mil/software/hec-hms/documentation.aspx> |
| **User’s assistance:**Not provided to non-Corps users. |
| **Additional information:** |

**HEC-RAS**

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| **Website:**<http://www.hec.usace.army.mil/software/hec-ras/> | **Developers:**Hydrologic Engineer Center, U.S. Army Corps of Engineers. |
| **Download:**<http://www.hec.usace.army.mil/software/hec-ras/downloads.aspx> | **Registration required:**Yes |
| **Technical features:**HEC-RAS allows the user to perform one-dimensional steady flow, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modeling.HEC-RAS has added the ability to perform two-dimensional hydrodynamic routing within the unsteady flow analysis portion of HEC-RAS. The following are examples of how the 2D flow areas can be used to support modeling with HEC-RAS:* Detailed 2D channel modeling.
* Detailed 2D channel and floodplain modeling.
* Combined 1D channels with 2D floodplain areas.
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| **Documentation (i.e. user’s manual, quick start guide, tutorials):**<http://www.hec.usace.army.mil/software/hec-ras/documentation.aspx> |
| **User’s assistance:**Not provided to non-USACE users. |
| **Additional information:** |

**SACRAMENTO MODEL**

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| **Website:**<http://www.wmo.int/pages/prog/hwrp/homs/Components/English/j04201.htm> | **Developers:**National Weather Service River Forecast Center in Sacramento, California |
| **Download:**[Available](https://www.epa.gov/water-research/storm-water-management-model-swmm#downloads) under request from the HOMS National Reference Centre for China:http://www.wmo.int/pages/prog/hwrp/homs/hnrc\_en.html#CHINA | **Registration required:**Not applicable |
| **Technical features:**Conceptual model that uses storm rainfall and evaporation to estimate runoff (flood forecasting). The model uses the concept of storage excess to compute the runoff volume and takes into account the non-uniform distribution of soil moisture over the basin. A three layer model is used to compute actual evaporation. Unit hydrographs are used to distribute computed runoff from the sub-basins, which are then combined by a stream routing procedure to give the basin outflow. The model structure is simple, involving about ten parameters. The time step used is one day, but this could be changed. |
| **Documentation (i.e. user’s manual, quick start guide) :**The user’s manual is provided. |
| **User’s assistance:** |
| **Additional information:**This model was included in the Hydrological Operational Multipurpose System (HOMS):<http://www.wmo.int/pages/prog/hwrp/homs/sectionJ_en.html> |

**TOPKAPI (TOPographic Kinematic APproximation and Integration)**

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| **Website:**<http://www.progea.net/prodotti.php?c=Software&p=TOPKAPI> | **Developers:**Prof. Ezio Todini, University of Bologna |
| **Download:**Under request | **Registration required:**Yes |
| **Technical features:**TOPKAPI is a fully-distributed physically-based hydrological model that can provide high resolution information on the hydrological state of a catchment. This model can be used both as a stand-alone program and inside real-time operational flood forecasting systems. Fields of application include:* Catchment hydrology
* Flood forecasting
* Water resources management
* Artificial reservoirs management
* Land use and climate change
* Irrigation and drought
* Landslides

TOPKAPI reproduces the behavior of the main components of the hydrologic cycle. Beside subsurface, overland and channel flow, it includes components representing infiltration, percolation, evapo-transpiration and snowmelt, plus a lake/reservoir component and a parabolic routing component based on Muskingum-Cunge method. Each model component can be activated separately. |
| **Documentation (i.e. user’s manual, quick start guide) :**Technical references: ftp://ftp2.progea.net/Web/TOPKAPI\_TechDoc\_ENG.pdf<http://www.progea.net/prodotti.php?c=Tutorials&p=TOPKAPI_Tutorials> |
| **User’s assistance:**Forum: <http://627295.xobor.com/>The technical support service has fees. |
| **Additional information:**A permanent educational version is available for students and researchers.Training courses (online and face-to-face) are provided annually. |

**WATFLOOD**

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| **Website:**<http://www.watflood.ca/> | **Developers:**University of Waterloo |
| **Download:** | **Registration required:** |
| **Technical features:**WATFLOOD is a menu-driven micro-computer based flood forecasting system incorporating data management programs to enable real-time use of weather radar for flood forecasting. It includes a radar calibration model called CALIBR and a simulation model called SIMPLE, which is the heart of the system. SIMPLE is a process-based hydrologic simulation model programmed in FORTRAN77. Only the most dominant hydrologic processes affecting flood flows are included. The programming for inputing streamflow, gage rainfall, and reservoir releases uses a spreadsheet type of input format.SIMPLE features an automatic pattern search optimization algorithm to determine which combination of parameters best fit measured conditions. The parameters for optimization are: soil permeability, overland flow roughness, channel roughness, depression storage, and an upper zone depletion factor. In the operational mode, the calibration option is used to determine the initial soil moisture based on real-time measurements of streamflow.Radar derived precipitation data is usually reported in a square grid format. WATFLOOD is designed to use digital radar data in various formats. Regardless of format, weather radar does not at present provide accurate rainfall amounts. The WATFLOOD system includes software to calibrate or adjust radar measurements in a real-time mode, using ground based telemetered raingages as ground truth. |
| **Documentation (i.e. user’s manual, quick start guide, tutorials):** |
| **User’s assistance:** |
| **Additional information:** |