WORKING GROUPS CONCLUSIONS AND RECOMMENDATIONS

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Abstract- This paper summarises the conclusions and recommendations of four working groups: WG1 on river floods, WG2 on ice jams, WG3 on low flows and WG4 on risk assessment.

Keywords: river floods, ice jams, low flows and risk assessment

1. Working Group: River Floods

Chairs: Dan Rosbjerg, Pieter van Gelder, Mikhail Bolgov

During the NATO workshop 21 papers were given on river flood related issues, presenting the state-of-the-art. In a Working Group meeting 19 participants[1] discussed research needs on river floods, with the following results:

[1] The Working Group had the following members: Dan Rosbjerg, Pieter van Gelder, Serge Prokopiev, Valery Savkin, Mikhail Bolgov, Vasili Rogunowich, Luis Garrote, Francisco Martin Carrasco, Pierre Hubert, Gabor Balint, Natalya Kichigina, Vladimir Maltsev, Pierrick Givone, Wladimir Trubnikow, Guenter Bloeschl, Tamara Berezhnykh, Dmitry Burakov, Youlia Avdeyeva, Paolo Reggiani, Boris Gartsman

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1.1. DATA COLLECTION AND ACCESSIBILITY

In many areas, there is a need for expansion and modernisation of the hydro-meteorological network and further development of remote sensing observations (satellite and radar). A problem is the lack of accessibility to existing datasets, since it is an obstacle for progressing research and operations. Easier data accessibility would be highly recommended. Catalogues of extreme floods are needed. The existing UNESCO and IAHS catalogues are inadequate at present. It contains weak input from the different countries and more detail is needed. A worthwhile approach could be to assemble a limited number of well-monitored case studies worldwide on flood events. Concern is about the very low number of scientists and engineers trained for research and operational forecasting in several countries. A recommendation is to attract more people and channel more financial resources towards this activity. The level of education needs to be improved and certified personal should be trained. Exchange of data between countries should be open and well organised. Since there is such a large difference worldwide in instrumental data collection, existing standards should be followed.

1.2. FLOOD MODELLING AND FORECASTING

Short-term forecasting is satisfactory with lead-times up to several days (depending of the catchment size). In both flat and mountainous terrain there is a need for better medium-term and long-term term forecasting of precipitation and river runoff in small as well as large catchments. In particular flood wave propagation including 2D inundation models should be improved. Also, improved air temperature forecasts are needed. All important processes should be accounted for, including soil moisture states and soil storage capacities, and the interaction between surface water and groundwater. Huge floods and flash floods may need particular attention. Efficiency of forecast products should be enhanced. Deterministic forecasting should be further developed and uncertainty bounds explicitly indicated (e.g. by means of ensemble forecasting techniques). The uncertainties need to be separated into input uncertainties, uncertainties related to model structure, and parameter uncertainties, and should be investigated individually.

The models should be continuously updated as new observations are collected and adequate data assimilation techniques should be further explored and become an integral part of the flood forecasting system. Grid sizes of numerical models should be refined and the linkage between atmospheric and hydrological models should be improved. Moreover, the linkage between pooling of different data sources (radar and rain gauges information) can be further optimised. An improved description of flood-generating mechanisms must be achieved by combining physical based models with statistical models. Duration of floods, which is crucial for the failure probability calculation, also needs to be observed and modelled. Long dry periods can lead to weakening of soils (especially peat) and subsidence of some types of soils. Finally, links have to be established between floods and flood plain ecology.

1.3. DESIGN AND PLANNING

Apart from the hydrological analysis an economic analysis should also be carried in the context of flood design. A monetary quantification is necessary to assess the consequences of flood-related disasters. Loss of life estimation is needed. Reduction of failure probabilities leading to smaller risks is aimed for until an acceptable level is reached. The effect of uncertainties on the design has to be modelled. Frequency-based methods, including joint probability models taking several processes such as rain, ice formation, wind surges, snow melt into account, should be further developed. This is necessary with respect to the selection of probability distributions, the detection of outliers, parameter estimation methods and regionalisation techniques (especially in ungauged catchments). Scaling techniques based on complete time series should be considered as an alternative and promising technique for the estimation of extreme events. Bayesian methods and other model updating techniques should be developed to become more applicable. With cost-effective flood design the tax payers' money is spent in an optimal way. New construction methods (such as sheet pile walls) should be further developed. Emergency measures given the start of a flood (sand bags, closing breaches by rock, or vessels), should be optimised. Design by PMF methods need to be further advanced for an effective and reliable design of hydraulic structures. Statistical models should incorporate physical based laws, when they are used for large extrapolation.

1.4. FLOOD MANAGEMENT, COMMUNICATION AND DISSEMINATION

Integrated flood management is needed and should include topics such as land use planning, flood defence design, financial aspects, regulation, etc.

Social problems should also be considered. The societal response to floods has to be further investigated. The gap between hydrological research and operational practice should be reduced. Forecasting results should be adequately disseminated to the public, and the limitations of the predictions should be clearly stated. The efficiency of forecasting products should be continuously improved, and made understandable for decision-makers. Public awareness and risk perception of floods should be raised. Decision-makers should be accustomed to handling probabilistic forecasts.

Communication channels such as GSM and wireless technology are developing and should be exploited for issuing of alerts.

2. Working Group: Ice-Jam Floods and Other Ice-Related Extreme Hydrologic Events: New Concept for Security

Chairs: R.Ettema, Z.Kundzewicz

2.1. INTRODUCTION

Ice has a major influence on the hydrologic behavior of many high- and mid-latitude watersheds. Accordingly, several extreme hydrologic events (EHE) may occur because of ice, such as ice-jam flooding, ice jam and ice run disruption of infrastructure (navigation) and damage to structures, notably bridges, ice damage to the river environment and ecological impacts of ice jams and ice runs. These may be affected by impacts of climate change on temperature-sensitive cold regions (e.g., melting of permafrost). Finally we may mention breaching of glacier-retained lakes (jokulhlaups)

The Working Group[2] focused primarily on EHE associated with ice-jam flooding, which is commonplace in Siberian rivers. River-ice jams can produce extreme flood events with major social, economic and ecological impacts. The overall goal of the Group is to find ways in which the very real economic-cost, and loss-of-life, consequences of ice jams in NATO countries and in Russia can be substantially reduced or even eliminated. It has long been felt that NATO countries would benefit greatly by linking their research and engineering efforts with those in Russia.

Ice jams are a reasonably common feature of rivers subject to cold winters. However, for most situations of ice-jam flooding, the present capacity of engineers and scientists to forecast the occurrence, extent, and

[2] The Working Group had the following members: Buvin, V. A., Burakov, D. A., Omelyanenko, A. V., Nogovitsyn, D. D., White, K., Zinoviev, A. T., Kundzewicz, Z. W., Ettema, R., Kilmyaninov, V. V., Belikov, V.

duration of ice-jam flooding typically is quite limited by gaps in knowledge and tools for addressing jam problems. The presence of ice can greatly complicate water flow through a watershed. Consequently, there are many difficulties in forecasting ice jams and the flood levels produced by them.

The Working Group discussed the information needs and uncertainties associated with forecasting ice jams, determining flood levels associated with ice jams, and mitigating jam occurrence and flooding. Additionally, the Group briefly discussed the state-of-the art regarding knowledge about ice jams, and it reviewed the developments needed in order to improve the ability of people to forecast ice-jam flooding.

2.2. STATE-OF-THE-ART ON JAM-FLOOD FORECASTING

Our ability to forecast ice-jam flooding, and to protect against ice-jam flooding, remains rather inadequate. Though we are able to understand most physical processes associated with ice jams, the task of combining the mathematical description of processes in a forecast model poses a formidable challenge. A major source of difficulty is the limited amount of data available with which to develop reliable forecast models of ice-jam flooding. This difficulty is intrinsic in the nature of ice jams, and is a difficulty that is not easily overcome in the near term.

Ice-jam floods are influenced not only by most of the same factors usually associated with river floods during ice-free conditions, but also by two broad additional sets of factors. One set pertains to thermal conditions, notably those governing ice formation and weakening; snow melt; and runoff. The second set pertains to the ways whereby flow conditions influence ice formation, ice breakup, and ice conveyance along a river; included here are the influences of water discharge, natural channel morphology (e.g., bends and confluences), engineered changes in channel morphology (e.g., channel narrowing), river use for water-resource purposes (e.g., water diversions), and the presence of certain hydraulic structures (e.g., bridges) along a river reach. Each of these additional sets of factors greatly compounds the overall uncertainty associated with forecasting floods.

Such factors as flow hydrograph, the thickness and strength of the winter ice cover are directly or indirectly influenced by weather conditions, which implies potential impacts of climate change and variability on the severity of ice-jamming (Beltaos & Prowse, 2001). The timings of freeze-up and breakup indicate trends that are consistent with concomitant changes in air temperature. Indeed, the ice break comes earlier in the warming world.

As shown by Beltaos and Prowse (2001), increased incidence of mid-winter breakup events and higher freshet flows in certain parts of Canada could enhance the frequency and severity of ice jams. Possible future trends under climate warming scenarios are discussed and associated impacts identified in a general manner.

The principal features of ice jams are well described in a number of books and monographs, many of which are available to practitioners and researchers around the world. However, there is a need for greater communication and sharing of information. For example, some books and monographs prepared in one part of the world are not immediately accessible to practitioners and researchers in another part of the world; language has been something of a barrier in this respect.

The Group noted the following references from several last decades as being of considerable use in understanding ice jams, and as indicating the state-of-the-art in ice-jam forecasting: Ashton (1986), Beltaos (2000), Beltaos and Prowse (2001), Donchenko (1975), Michel (1978), Nezhikovskiy (1964), Pariset et al. (1966), Shulyakovskii (1966, 1972), Uzuner and Kennedy (1976). Additionally the Group noted the recent book by Dr V. Buzin (2004), and the various research monographs prepared by CRREL (http://www.crrel.usace.army.mil/), such as Daly (2003), White (1999), and Zufelt and Ettema (1997).

2.3. RESEARCH AND DEVELOPMENT NEEDS

The Group identified three sets of research and development needs, i.e. resource difficulties, field monitoring difficulties, and gaps in knowledge about physical processes and modeling.

Before listing the main gaps in knowledge about processes, it is important to outline two important sets of practical difficulties currently faced in advancing the state-of-the art in ice-jam forecasting. These practical difficulties concern the resources needed for working on a complex subject like ice-jam flooding, and the often hazardous and dynamic conditions entailed in obtaining measurements of jam data.

2.3.1. *Resource Difficulties*

A major problem is the highly constrained funding available for developing the knowledge base needed for effective forecasting of ice jams. This difficulty is especially severe in Russia, which has innumerable rivers subject to ice-jam flooding. In particular, the inadequate and decreasing funding of observational hydrologic network is a concern. Such a network would aid flood defense measures, and thereby provide enhanced security against ice-jam flooding.

Russia, and to somewhat lesser extents Canada and the U.S., cover large areas. Russia is a vast country in which distances are very large, and many areas are sparsely populated. Consequently, it is not easy to monitor many rivers for ice jams. The vastness of Russia, in particular, hampers collaboration between the various groups of people and agencies involved in work related to ice jams. This difficulty is compounded by the problem of meager funding.

Communication between groups involved in ice-jam work is inadequate. Not only has technical communication between the North America and Russia been very limited, communication among groups within Russia seems also to be quite limited. This difficulty too is compounded by funding difficulties. It has restricted the sharing of knowledge, and it has limited recognition of the extensive work done by Russian engineers and scientists.

Development of a data base on ice jams in Russia is a very important, but complicated task. Besides challenges posed by the vast size of Russia and the huge number of rivers prone to ice jams, data-base development has been disadvantaged by lack of funds and inadequate communication (which itself is affected by lack of funds). Concern was expressed regarding the shrinking network of hydrologic monitoring in Russia. The network is becoming too sparse, has significant gaps, and acquisition of hydrologic information is becoming increasingly difficult. Remote sensing and geophysical methods hold promise but are not adequately utilized.

Because field monitoring and database establishment involve the use of advanced technologies, it is important that the multi-disciplinary character of ice-jam monitoring be recognized and embraced. Multi-disciplinary efforts can be difficult to conduct. Ice-jam monitoring and forecasting, arguably, more than open water flooding, requires a multi-disciplinary effort.

2.3.2. *Field Monitoring Difficulties*

1. The irregular nature of ice jams complicates the acquisition of field data and observations on ice jams and the floods they cause. For example, satellite monitoring of ice jams often is made difficult by the speed with which ice jams form, and by weather conditions (cloudiness). Also, the localized nature of ice jams typically requires more detailed and frequent observations. Though jams commonly re-occur at particular locations, their occurrence can be difficult to forecast. Furthermore, jams can form at several places during the same overall event. Apparently, for instance, jams may occur each year at some of about 125 ice-jam prone locations on the Lena River.

2. Guidance is needed on forming useful databases that conform to the recommendations of the World Meteorological Organization. Such guidance would help researchers better access and use information in an ice-jam database. Presently, an effective structure of an ice-jam database has not been established.

3. The dangerous nature of ice jams creates many difficulties in obtaining key data on ice jams. For example, it is difficult to get data on ice-jam thickness variation, on jam strength characteristics, and on flow depth, and on possible channel scour below jams. Specialized equipment must be more widely used and additional equipment developed.

4. To guide future development, and for damage-insurance purposes, it is necessary to delineate flood levels. However, estimation of the zone of ice-jam flooding is difficult because of the highly variable nature of many jams. This practical aspect really shows how ice presence adds much uncertainty to flood forecasting.

5. Because of the difficulties in accurately forecasting ice-jam flood levels, real-time monitoring and data collection is very important. Such monitoring and data collection is needed to update flood models continuously, and to predict possible adverse effects of further jam development and possible release; release may cause a severe surge or result in jam re-formation downstream.

6. By virtue of the rarity of extreme events, observations on extreme ice-jam events are lacking. Efforts and resources are needed to document such rare events when they occur.

It was mentioned that ice jams in Russia have been recorded for a long time, and that considerable efforts at recording jams have been made during the past 60 years. However, funding difficulties along with lack of certain hydrologic data are severely restricting the further recording of ice jams in Russia. A useful goal would be for Russia to have an ice-jam database similar to that developed by CRREL in the USA.

The estimation and modeling of heat transfer at the water-air and ice-air interfaces, though quite complicated, is not the main limitation in accurate forecasting of ice-jam flooding. Rather, one major limitation is the paucity of information characterizing hydro-meteorological conditions in watersheds. Moreover, a second limitation is associated with the need to quantify the behavior and movement of ice under changing flow conditions. This latter difficulty is arguably the main difficulty in establishing rigorous and reliable forecasts of ice jams and the floods they may cause. And it emphasizes the importance of having an effective system of hydrologic monitoring.

2.3.3. *Knowledge Gaps*

Given that ice jams and the floods that they may cause are the result of many processes, it is difficult to prioritize knowledge gaps. To be sure, there are many gaps, both in understanding of physical processes and in methods to prevent or mitigate ice jam problems. The Working Group identified many important knowledge gaps, and clustered them in the ensuing sets:

UNDERSTANDING OF ICE-JAM PROCESSES AND THE LINKS BETWEEN THE PROCESSES

1. Improved estimation of snow accumulation patterns in watersheds, and of snow-melt runoff. Runoff estimation should not only include overall (maximum) rate of runoff, but also the temporal changes of runoff, and in particular the details of the growing limb. More needs to be understood about how runoff hydrograph steepness affects ice-jam formation.

2. For jams in alluvial rivers, the influences of runoff-hydrograph duration, and ice-jam duration, should be investigated, insofar that flow duration may influence jam effects on river morphology.

3. Much more needs to be known about ice-cover formation during early winter, especially on the way freeze-up jams form and how they affect flow transport of ice after ice cover break up.

4. Further understanding is required about how river morphology affects the formation of freeze-up and break-up jams. It would be useful to delineate reaches of rivers that are especially vulnerable to ice jams. Delineating ice-jam areas is important in preventing development.

5. More also needs to be known about how jams evolve. In this regard there is a need to better understand how weather variations affect jam formation and collapse (e.g., wet or dry antecedent conditions in a watershed, fluctuations in air temperature).

6. Aspects related to orientation of a river need to be examined. There are questions about how rivers flowing East or West freeze-up or break up relative to rivers that flow North or South.

7. A general set of issues concerning the effects on ice-jams of the relative scales of heat flux, flow rate, and channel size.

8. Further information is needed on the strength properties and behavior of ice jams. Accumulations of ice rubble are unique particulate material whose strength behavior has a large degree of uncertainty.

IMPACTS OF ICE JAMS AND FLOODS

1. Better ways are needed for estimating likely flood levels associated with ice jams. In this regard, further analysis of existing data is needed. Additionally, numerical models could be developed further and used to relate flood levels for various scenarios of jam formation at selected river reaches.

2. More needs to be known about the interactions of ice-jam formation and alluvial channel behavior. One concern in this regard is the transport of bed sediments containing contaminants.

3. Determine the effects of ice-rubble abrasion of river banks and river-bank structures.

The effects of ice jams on the river environment comprise another large area where knowledge is lacking. In this regard, also to be investigated are the environmental consequences of various ice-control activities.

METHODS OF QUANTIFYING AND MODELING ICE-JAM IMPACTS

1. Further improvements in the formulation of component processes associated with ice jams.

2. Numerical modeling of ice-jam formation and ice-jam flows is still in its early stages. Not only does such modeling have to cope with all the complex problems involved with modeling of open water flows in rivers, but it also has to handle the additional complications associated with ice movement and accumulation. Rigorous, physically-based, models are of limited practical applicability due to huge, hence difficult-to-meet, data requirements. Though numerical models currently are capable of modeling ice-jam formation and flows in ice-covered channels, there still exist important knowledge gaps related to the development and effective use of numerical models.

3. Remote-sensing and air-borne methods for monitoring ice jams need to be further developed.

METHODS FOR CONTROLLING ICE JAMS

1. There remain many aspects of ice-jam control that need to be examined further. Included here are ice-control structures, ice booms, engineered ice jams upstream in watersheds, and non-structural activities such as use of ice-breaker ships or blasting of ice jams. Ice-breaker services, being commonly used on large northern rivers and lakes, are important control of ice-jam forming. It was mentioned that Dr V. Buzin had recently prepared a review on jam blasting for the Russian Ministry of Emergency Situations.

2. An area of knowledge need concerns reservoir operation with one objective being risk management for ice-jam development.

FORECASTING ICE JAMS AND FLOODS

1. Of particular importance is determining methods for extreme water levels developed by ice jams, especially for regions where there is a lack of long-term hydrologic data.

2. Ways need to be developed and implemented for monitoring ice covers.

3. There is a wide knowledge gap concerning the influence of climate variability on ice jams. The influences are not full understood, and may be unexpected. For example, very tentative recent experience with rivers in Siberia suggest that drier Autumn weather (less snow) has resulted in thicker ice growth on the rivers. Anecdotal evidence in North America suggests a similar trend. Additionally, early observations suggest the more frequent occurence of break-up jams, which then may reform. Factors such as more rain-induced runoff in winter are possibly contributing to these changes. In large parts of Europe, ice-jam floods are less frequent and less severe (Mudelsee *et al.,* 2003, Kundzewicz, 2002). Mudelsee *et al.* (2003) detected significant downward trends for winter floods in Central Europe. Kundzewicz (2002, p. 237) stated: "It was reported from much of Europe that ... less snow cover may reduce the severity of spring snowmelt floods ... It seems that, where the rivers freeze, milder winters lead generally to thinner ice cover and shorter persistence and reduce severity of ice jams. Ice-jam related floods are not a major problem anymore in much of Europe, where the rivers freeze less often in the warming climate (with industrial waste heat playing also a role in many locations)." Ice jams and ice-jam flooding, which were common in the Netherlands over centuries, and even decades ago, have disappeared.

The overall greatest deficiency in knowledge concerns forecasting of flood levels associated with ice jams. This deficiency essentially integrates many of the component gaps in knowledge listed above. Viewed together, these sets of knowledge gaps indicate the need for a concerted major program of research and development concerning ice jams, especially in Russia where ice jams are such a prominent and recurrent feature of many watersheds.

2.4. NEW DEVELOPMENTS AND NEXT STEPS

The new developments and next steps are aimed at substantially reducing, or even eliminating, the very real costs, and loss-of-life, which are consequences of ice jams in NATO countries and in Russia. It is felt that NATO countries would benefit greatly by linking their research and engineering efforts with those in Russia.

Several new developments can be made. The present NATO workshop has served as an important early step in facilitating certain of the developments but next steps are necessary. The Workshop was a very unique occasion for engineers and scientists from Russia and NATO countries to get together to prepare a structured view of the major problems caused by ice jams, of the main gaps in knowledge, and to indicate how we should proceed to address the problems. There was a consensus within the Working Group that there should be substantive follow-on to this NATO Workshop.

The new developments and next steps are in two general categories: Communication and collaborative effort; and use of enabling technologies to advance science of processes and modeling capabilities. A feature common to both developments is the use of the Internet, which enables easy communication, as well as aids in the use of various measurement and data-transmission methods, and thus facilitates collaboration.

A point to be emphasized is the need for a long-term effort at developing a sound knowledge base, and set of tools, for addressing ice-jam problems. It is not sufficient that the efforts be ad-hoc, responding only to specific local emergencies. A further point is that the collaborations should involve researchers and practitioners alike, including people engaged in operating river systems and in dealing with ice jams.

2.4.1. *Communication Developments*

Several new developments are to be considered and pursued:

1. Joint studies (involving Russian and NATO researchers and practitioners);

2. The pairing up of Russian and NATO researchers with the goal of joint research and publications;

3. Seminars and workshops or symposia;

4. Study tour of Canadian, U.S. and Russian rivers that are subject to ice jams.

The NATO program of NATO Colaborative Grants can help with the communication and collaborative efforts by providing seed money. NATO and Russian scientists and engineers are encouraged to obtain such grants and also vigorously pursue other funding options.

Some specific ideas for collaborative studies are as follow:

- Joint projects in the area of field monitoring. Such projects would seek to combine the unique capabilities of counterpart research partners.
- Case-study projects, such as involving the ice-jam problems on the Lena River, could be developed.
- Comparitive studies of ice-jam characteristics. Such studies could entail sharing data from Russian and NATO watersheds, and comparison of results from numerical-model simulations.
- A well-focused workshop that compares ice processes observed on Russian, Canadian, and U.S. rivers. The workshop could be held, for instance, in Yakutsk, a City on the Lena River, Siberia; Anchorage Alaska; or, perhaps at Dawson City on the Yukon River.
- Study tour of Russian, Canadian, and U.S. rivers that aim to gather specific information of ice-jam problems and the ways in which the various problems are handled.
- Collaborations involving the pairing of U.S./Canadian researchers with Russian counterparts.
- Translation of important Russain books and monographs into English.
- A joint review, or a state-of-the-art paper, co-authored by Russian and North American scientists and engineers engaged in ice-jam research.

2.4.2. *Enabling Technologies*

Developments in sensors and sensing networks, together with modeling, hold considerable promise for providing the information on the thermal aspects of ice-jam forecasts. Such greater knowledge for forecasting, in itself, is not enough. Also needed is improved understanding of processes, e.g., knowledge of how flow conditions influence jam formation, and how adjustments in river management, channel morphology, location of hydraulic structures, and land use could mitigate ice-jam flooding.

1. Developments in numerical modeling of ice jams, as well as flow in ice-forming rivers.

2. Emergency triggers developments in preparedness and research projects that result in improved preparedness. There is a need to ensure that such preparedness is maintained. This requires that adequate funding be maintained even though no floods occur (e.g., like airport security). It is worth to remember that the time after flood can be also perceived as the time before the next flood.

2.4.3. *New Concepts for Security*

The new developments create the bases for new concepts in security with respect to extreme hydrologic events in cold regions. Communication and improved capabilities in modeling and monitoring will have substantial effects on our ability to mitigate the damaging consequences of ice-jam floods. However, the new concepts require investment.

3. Working Group: Low Flows, Climate, and Environment

Chairs: Daniel.P.Loucks, Leonid Kutchment and Bart Fokkens

Currently in Russia relatively little attention is being given to low flow and environmental problems compared to floods, yet the problems associated with these conditions are important. Some research is done in other countries, associated with problems in the fields of quality control, ecological balancing, navigation, ice control and others. The working group[3] discussed a number of relevant issues and identified the following important research topics:

3.1. LOW FLOW DEFINITIONS

We need improved statistical methods to characterize drought conditions similar to the methods available for and being used for characterizing flood conditions. These methods should not be only for

[3] The working group consisted of the following members: Daniel P. LOUCKS, Günter BLÖSCHL, Bart FOKKENS, Oleg F. VASILIEV, Anatoly M. VLADIMIROV, Tamara V. BEREZHNYKH

planning, but we also need improved long term forecasting methods to predict the potential of low flows, based in statistical methods and on observations such as snow cover at the end of the winter, or of el Nino/ la Nina events. At present, low flows are defined as those that are exceeded 80% of the time. This definition has no scientific basis, and research is needed to determine a rational way of characterizing such flows.

Different definitions of low flows are needed according to application. For example, low flow information to be used for defining droughts indicators for agriculture differ from low flow information needed to maintain water quality in rivers.

3.2. LOW FLOW CAUSES

Low flows are generally base flows resulting solely from groundwater discharges into streams and rivers, but there exist also controlled low flows downstream of dams or barrages. In Russian winters, groundwater seepage to the soil surface freezes, therefore low flows, if at all, are often from alluvial deposits, whereas surface runoff from watersheds is minimal. These processes are poorly understood.

Therefore, research is needed to better understand the processes of hydrology that result in low flow conditions, i.e. the hydrogeological processes involved in converting precipitation to stream and river flows during all seasons. These processes are especially complicated in permafrost areas or in winter seasons, when groundwater flows are subject to freezing events. For example, the time lags associated with these processes may change, or formation of ice on ground surfaces, or on top of snow pack may influence the precipitation - runoff process.

Due regard should be given to potential or actual changes in climate, which may impact such processes as runoff, groundwater-surface water interactions, and other processes, and studies on the possible changes resulting in particular from warmer climates would be very useful.

3.3. CONSEQUENCES OF LOW FLOWS

Not enough is known to determine the impacts of long periods of low flow conditions, for example during periods of drought. The consequences on drinking water and water for irrigation are obvious.

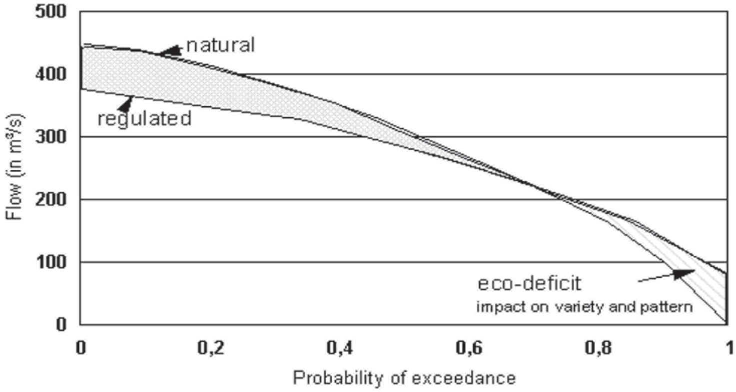
In many countries overriding issues stem from water quality aspects. Waste loads discharged into rivers under low flow conditions have greater adverse impacts than when river flows are higher and provide greater dilution. In Austria, and much of Western Europe, wastewater discharges are required to meet effluent constituent concentration standards, rather than meet stream or river quality standards. Similarly in the US, except when those effluent standards fail to meet water quality criteria. Currently Russia has no operational wastewater effluent or stream quality standards. Alternatively, the effluent control is not a direct control of the river water quality, and therefore, it is often suggested to use the principle of immission control, where the water quality of the river forms the basis for deciding the water quality of the effluent. This is usual for the control of the quality of groundwater used for drinking water. In Austria and in Germany, ground water quality standards are stricter than surface water quality standards, and in any streams where surface waters enter groundwater the surface water quality should not degrade the groundwater quality.

There is a need to establish criteria for setting wastewater effluent and stream water quality standards in Russia, and the principle of immission control might be the better way to obtain optimum economic solutions of pollution control, with immission standards which might vary not only based on water use but also on the climatic and ecosystem conditions in the region. When economic conditions improve there will likely be more attention given to environmental protection and ecosystem preservation, and the decision on which type of standards to use should be carefully evaluated.

3.4. LOW FLOW CONTROL

Hydrologic flow and quality requires to consider influence of natural geomorphological and ecological processes. This includes occasional low and flood flows. However, low and flood flows usually bring adverse economic impacts. Low flow can reduce navigation and recreational benefits and can be harmful to fish. Also, it can affect water intakes and water quality. The challenge we have is determining how to manage flow so as to maintain healthy diverse ecosystems.and at the same time provide reliable economic and social benefits. This implies to modify environmentally degraded river reaches (or maintain well functioning ecosystems), according to the eco-deficits identified in Fig. 1.

Managers of flows in rivers are challenged by these conflicting needs of nature which benefits from variable flow conditions, and those of human users (for hydropower, navigation, recreation, etc.) that benefit from more steady and reliable flow conditions. Russia, as well as many countries in semi-arid countries need low flow and drought condition monitoring and mapping, both for planning and for real-time management. In some regions of Siberia and other regions water demand frequently exceeds water supplies. Improved efficiencies of irrigation and other water uses are needed especially in these regions. Research is needed regarding the regulation and augmentation of streams and rivers during low flow conditions – including methods of flow augmentation through interbasin transfers, as is planned in China on a large scale.



To maintain low flows at desired level for water supply and water quality, operators of hydropower installations are challenged to adjust control of dams, while at the same time optimizing power production. Different patterns of seasonal and annual low flows and runoff have different impacts on hydropower operation. Predictions are needed for up to two years in advance to estimate the duration of extreme low flow conditions, and to adjust operation strategies accordingly.

4. Working Group: Risk Assessment and Risk Management

Chairs: H.-P. Nachtnebel, S. Bednaruk and E.J. Plate

Working group 4 had the task of defining some critical issues in use of and calculations for risk management. However, the broader issue of risk management was only touched upon. The discussion focused on risk assessment, which is the task of determining the elements that make up the risk. Mathematically speaking, risk is the expected value of a function K of the random variable Q. Risk as expected value of consequences is more general than just risk for large floods, although the discussion concentrated on this aspect. It also describes consequences due to low flows, and risk for water pollution issues or for meeting the demand by a water supply system is expressed in the same way.

Risk assessment requires to identify two essential quantities; the probability function for the extremes Q, and the consequence function K. Risk analysis combines these functions into the risk and derives conclusions from the resulting expected value. Working group 4 concentrated on the consequence function. The most significant conclusions derived during the sessions are briefly summarized in 14 points.

4.1. CONCLUSIONS FROM THE WORKING GROUP DISCUSSIONS

1. Use of risk analysis is restricted to the planning of larger systems or elements. In this sense it is used for the ring dikes in the Netherlands, and it is started to be used for the large systems of the Corps of Engineers in the USA.

2. A difference of the role of scientists in risk analysis is became apparent: The view was presented that cost and benefit analysis is not an issue for hydrologists. Others think that societal issues should be included in scientific decision concepts.

3. Risk analysis is an outcome of the desire to put an objective measure on decisions, in particular if risk is the expected value of monetary consequences. In this form, risk is a required quantity in a cost benefit analysis. Risk based design broadens the perspective from probabilistic design standards to consider also the consequences as well as multiple failure modes. Important outcomes of risk analysis are hazard maps, and flood risk maps. The preparation and use of such maps is recommended, and has standard in many western countries.

4. Risk can be used as a measure to compare flood protection benefits with benefits from other societal projects, or of different alternatives for a flood protection project.

5. Results of risk analysis should be made available to the public, and public participation is essential for the decision process leading to a flood control system and its operation. There is a need for development of effective approaches to communicate flood risk and flood risk management to the public.

6. Risk analysis puts the value of extreme value analysis into perspective. Extreme value analysis in risk determination is important, but the estimation of the extremes of the distribution is uncertain. However, in some cases the consequences do not change much with the increase in recurrence interval (decrease in annual exceedance probability).

7. Evaluation of the present risk is comparatively simple. However, it is also important to predict future risks, which requires anticipating what will happen after a system has been constructed. This should include

changes in the potential damage, due to increased use of the protected land by industry and private persons, and due to changes in the extreme value distribution: caused for example by human intervention (dam break floods, floods due to dam operation), and also effects of climate change and land use changes. However, the increase in losses after flood dikes have been constructed should be compared with the benefits gained from the measures. The evaluation of system performance and development of potentially endangered developments should be re-evaluated regularly, as should also strength and adequacy of components, for example in the Netherlands reassessment every 5 years of the safety of the ring dikes is required.

8. Guidelines are needed for the safety analysis of large structures, such as dams and important dikes. Risk is useful as assessment criterion.

9. Assessment of risk requires a good data base. Geophysical data become more readily available with progress in remotes sensing and other technologies.

10. In the analysis of flood problems the role of sediments and sediment transport has to be considered. These include scouring and deposition as well as quality issues such as transport of pollutants and ecological impacts on fauna and flora.

11. The resistance of existing dikes to overtopping should be investigated and improved, involving the local population (for example, quality of grass cover is important). For suitable situations geotextiles should be considered.

The remaining points discussed by the group refer to flood risk management, which is seen as the sum of all actions necessary to develop, construct, maintain, and operate a flood protection system.

1. Risk management is more than risk assessment. Among the tasks of risk management are forecasting and warning. The benefits of forecasting and warning should be realized more extensively: forecasting not only for water supply but also for floods. Part of the forecasting activity must be the assessment of its reliability with respect to the considered application. Appropriate early warning and education of the population at risk are essential.

2. The role of insurance in flood damage compensation is extremely important. New developments are taken place in privatization: Governments now compensate above a certain level, but in future insurance should cover flood damage in many countries.

3. The importance of ecological considerations is stressed, ecological floods and considerations for management of rivers and polders ecologically are to be included into flood management strategies.

4.2. RESEARCH NEEDS ON FLOOD RISK (A SELECTION)

Due to time limitations it was not possible to discuss more than a selection of relevant research topics. Open questions requiring further research exist in every aspect of risk management, in particular if risk management is understood to include also non-engineering solutions to flood problems, and the inclusion of social and environmental issues into the risk assessment procedure. The requirement of forecasting future developments is not necessarily a task for engineers, who should, however, interact with social and environmental scientists to develop appropriate strategies for including these factors (and their uncertainty) into the planning activities for flood protection systems.

Risk assessment procedures today are well developed for risk cost estimation. But costs are not the only consequences to consider. How should one include social and environmental issues into the risk estimation process? Needed is a methodology of assessing the consequences of floods in the economic, social, human safety, and ecological domain.

Develop regulations and guidelines for locally adapted structures in flood plains. International guidelines for quality control of water defences infrastructures are needed, which should reflect most recent research findings.

At present, extreme value analysis does not usually consider the causes and structure of the meteorological, geomorphological, and topographical condition of a region. Rainfall runoff models with precipitation inputs, on the other hand, usually are not detailed enough to yield accurate estimates of extreme floods. .Harmonization of approaches for flood probability estimation over a broad range of probabilities and hydrological contexts, incorporating physically-based and statistical models are needed.

Coincidence of extreme events of different causes (such as floods and wind, storm surges and river floods, ice jams and snow melt, landslides) should be analysed.

The role of groundwater re- and discharge during floods should be considered in more detail. Urban development, highway construction, soil compaction by heavy agricultural machinery can reduce groundwater recharge and the storage capacity for flood waters. There is a need to study the role of ground water systems in storing flood waters, and examine their potential for flood mitigation and low flow augmentation.

Reservoirs for power generation usually are operated to maximize energy production, but usually they also contain some free space to accommodate floods. New knowledge of hydrological inputs, or of downstream development, may change the flood protection capacity of the reservoir. Therefore, the present operation of reservoirs should be reanalysed in the context of risk management and appropriate operation rules should be developed – which also should include low flow regulations to protect the fauna and flora of the downstream sections. Reservoirs are important elements in any action programs designed for such impacts. Predicting short and long term impacts of alternative regimes on ecosystems is a prerequisite.

Educational programs should be developed to inform the public and prepare people in endangered regions of the hazard to which they are exposed. These include training programs for children and relief personnel, but also the development of public participation strategies appropriate to the region and the population.

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