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A comparison of monitoring methods to quantify runoff and nutrient losses in Poland and Norway

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Introduction

In 2009 during International Workshop on Status and Perspectives of Hydrology in Small Basins held in Goslar-Hahnenklee, the researchers who are working on experimental basins worked out so called Braunschweig Declaration (Littlewood et al. 2010). The declaration is actually the reminder that "Realizing the relevance of environmental changes (e.g. climate and land-use changes), the value of long-term measurements in small research basins has become more important, for instance to cope with issues of non-stationarity in hydrological processes. Knowledge gained from studies in small hydrological basins can be used for decision-making with respect to managing ecosystem services and water resources systems" (Littlewood et al. 2010). The need for environmental monitoring, of both water quantity and quality, has been of course identified much earlier. For example, the UNESCO hydrological decade (1965–1974), had a strong impact on the development of studies related to hydrological processes at the catchment scale. However, over time, the need for monitoring systems and the development of new monitoring techniques in the field of water quantity and quality, remains the same. In 1990, 25 years after the International Hydrological Year and the International Hydrological Program, the need for data acquisition is still very important (UNESCO 1990). Actually, in EU – Water Framework Directive a major water law (point 36) indicates: „It is necessary to undertake analyses of the characteristics of a river basin and the impacts of human activity, as well as an economic analysis of water use. The development in water status should be monitored by Member States on a systematic and comparable basis throughout the Community. This information is necessary in order to provide a sound basis for Member States to develop programs of measures aimed at achieving the objectives established under this Directive" (Dz.U.UE.L.00.327.1).

In both Poland and Norway, monitoring programs are carried out with the objective to get information about hydrology and water quality. This paper compares monitoring methods in some selected catchments in both Poland and Norway.

Results and discussion

Water system monitoring in Poland

The monitoring and measurement rules connected with water environment in Poland are determined in a number of laws in case when are conducted by governmental agencies like Institute of Meteorology and Water Management (Polish abbreviation: IMGW) or Chef Inspectorate of Environmental Protection (Polish abbreviation: GIOŚ) in a frame of State Environmental Monitoring. The parental regulation is a Water Law (Dz.U. 2001 Nr 115, poz. 1229), where the major rules of water monitoring are determined. According to this law, the water monitoring is to obtain information about the state of surface waters and groundwater for water management planning and assessment of achieving environmental objectives (article 155a of the water law) and references methodology and the conditions for quality measurement and research (article 155b point 1F) are determined in a form of detailed ordinances. The ordinances from 6th of November 2008 (Dz.U. 2008 Nr 225, poz. 1501) deal with standard method of information gathering and processing by governmental hydro-meteorological service and hydro-geological service. The second ordinance from 13 may of 2009 (Dz.U. 2009 Nr 81, poz. 685) about forms and ways of monitoring bodies of surface water and groundwater, where the information about frequencies and the methodologies (usually in a form of European (ISO) or Polish Standards (PN)) of water quality and quantity monitoring for particular parameters or contaminants are described. Depending on the purpose of the monitoring, the three types of the monitoring system can be used: diagnostic, operational and research monitoring (Dz.U. 2009 Nr 81, poz. 685 paragraph 4 and 5). Generally, the diagnostic monitoring is for determination of status of water bodies and long term changes, operational is for determination of water bodies which have been identified as at risk of failing to meet their environmental objectives and research monitoring is for explanation of not achieving environmental goals specified for a given body of surface water.

An important aspect in water quantity and quality monitoring is the determination of water discharge which: 1) provides information about the runoff and 2) facilitates the calculation of the contaminant load. The most basic data which is gathered in Poland is water stage at certain time step, usually once a day at 6 UTC or during extraordinary events like floods three times a day at 6, 12 and 18 UTC (Byczkowski

1999). The discharges are measured usually by current meters, however last time the acoustic – Doppler method has been applied for discharge determination by IMGW (Maciążek and Mroziński 2009). Based on simultaneous water stage and discharge, the rating curve for particular measuring point is prepared. After the verification, the rating curves are used for determination of daily discharges. The rules connected with hydrometric methodology are published in a number of publications and manuals (Pasławski 1973; Różdżyński 1998; Byczkowski 1999).

The measurement of water quality is usually done by Voivodships Inspectorate of Environmental Protection by certified laboratories. These Inspectorates are responsible for the water quality monitoring at their terrain, which consists of 16 Voivodship. The goals and rules are written in the Inspectorate of Environmental Protection Act (Dz.U. 2007 Nr 44, poz. 287). The Chief Inspectorate of Environmental Protection prepares The State Environmental Monitoring Programme, which is valid for a certain period of time (the latest is for year 2010–2012) and describes the precise structure of the monitoring system. One of the parts is a state bock which consists of the following seven subsystems with water quality monitoring subsystem among them (Chef Inspectorate… 2009). The tasks to be implemented within the framework of the surface water quality monitoring subsystem in the years 2010–2012 will include: the measurements and assessment of the status of rivers, the measurements and assessment of the status of lakes, the measurements and assessment of the quality of bottom sediments in river and lakes, the measurements and assessment of the ecological potential and the chemical status of dam reservoirs, the measurements and assessment of transitional and coastal waters, the measurements and assessment of the status of hydromorphological elements of all surface water types. Each of the measurement includes objective scope, implementing entities, submission of measurements and assessment results and dissemination of results (Chef Inspectorate… 2009). It is worth to point out, that within the State Environmental Monitoring, the Integrated Monitoring of Nature Protection on eight Base Stations is conducted since 15 years (Kostrzewa and Kruszyk 2009). Its task is to observe the greatest possible number of elements of the natural environment, based on a planned, structured study time.

Except the governmental services, the individual Universities developed, over the years, their own environmental monitoring systems usually restrictive to small river catchments (Osuch et al. 1995; Hejduk et. al. 2010). The scope of such environmental monitoring depends on the research objectives (Hejduk et al. 2010). In same cases, the temporary monitoring systems are developed for solving specific problems in particular catchments (Banasik 2005; Hejduk 2007). Most of the monitoring rules follow the legal regulations. However, very often, the data acquire and applied methodologies are much more precise.

Zagożdżonka catchment an example of research monitoring system in Poland

History of monitoring system in Zagożdżonka catchment

The monitoring system consists of two stations at Czarna and Płachty Stare villages (Figure 6.1). The main station is located at Czarna. In 1982, the mill weir built in the fifties of the twentieth century was repaired and adapted to measure the water flow and become the Czarna station. A gauging staff, limnigraph and measuring V-noch weir – a sharp edge type, allowed to measure the water flow rate (Banasik et al. 1985). In 1992 the Czarna station was fitted with an automatic measuring devices: two sensors to measure stages (company SEBA and Trax Elektronik), temperature sensor, turbidity sensor and bathometer (device for taking a water sample regards to water level during flood propagation). In addition, a meteorological station was established near the Czarna station and equipped with: psychrometer, thermohigrograph, Hellman' rain gauge, mechanical pluviograph (daily and weekly type), two electronic rain gauge (tipping bucket and string type) and an electronic thermometer, hygrometer and barometer. All electronic devices are controlled by an electronic recorder developed by Trax Elektronik company from Krakow. Additionally, the Czarna station was completed with programmable automatic water sampler (American Streamline 800SL Sigma) with possibilities of cooling of the water samples (Górski and Hejduk 1998).

In 1997, the Czarna station was additional equipped with settling tanks to collect suspended sediment from long periods of time and the collected sediment were analyzed for granulometric composition using the laser diffraction method (Hejduk and Banasik 1999 and 2002; Górski et al. 2000; Banasik and Hejduk 2006). In 1998, about 200 meters upstream the Czarna station the bed load trap was build in river bed for measuring bed load transport. The trap is equipped with an electronic registration weight system (Popek 1999 and 2006).

In 2002, close to the bed load sediment trap the time integrated suspended sediment bathometer BS-2 was installed (Banasik and Hejduk 2005). In 2003 studies related to snow-melt floods were started and 4 ground thermometers (0,5,10 and 20 cm under the surface) were installed as well as heated tipping-bucket rain gauge. During the winter periods, water equivalent of snow and thick snow cover using Chomicz type snow sampler were carried out (Hejduk 2009). In 2007, for control of water levels, the cameras for taking pictures of gauging staff were installed. The meteorological station at Czarna station was supplemented in 2008 by albedometer and 4 ground piezometers equipped with water level and water temperature sensors – Diver (manufactured by Ejikelkamp Agrisearch Equipment). Since 2002, sensors of this type are also used as a backup sensor for water stage measurements of both station Czarna and Płachty Stare. In 2009, the automatic measurement at Czarna station was extended by integrated sensors DS5X Hydrolab water quality (manufactured by OTT Hydrometers Company LTD) and the device called Phosphax (manufactured by Hach-Lange) to measure concentrations of dissolved phosphate and total phosphorus. The two water velocity meters (AV stands for area velocity) to measure the speed and flow (model 2150 AV company Teledyne ISCO) were installed the same year. Furthermore, in 2009, a new gauging station equipped with an electronic sensor (Diver) were installed in the upper part of Zagożdżonka catchment (Okólny Ług gauge).

Płachty Stare gauging station was set up as a staff gauge point in 1962. Measurements of water stages were carried out, from this year, by the observer in accordance with the principles of measuring IMGW. Rainfall measurements began in 1983, but in the years 1996–2008 the rainfall measurement were suspended. Measurements of rainfall were resumed in 2009 with the use of the electronic Hellman's type tipping bucket rain gauge (RG-50 type with SEBA registers). Since 2002, water stages and water temperature have been recorded by electronic sensors. In 2002 the Płachty Stare gauge station were equipped with suspended sediment bathometer BS-2 similar to the one installed close to sediment trap at Czarna station.

In 2005, the additional water level sensor and water temperature sensor (Diver) were installed at the crest of the weir of Staw Górny reservoir. In 2007, the Płachty Stare station was additionally equipped with solar-powered system of data transmission to the Internet and equipped with a sensor of water stage direction and speed sensors. In 2009 the multi-parameter water quality sensor Hydrolab were added to Płachty Stare gauging station.

Transmission system, water discharge and nutrient monitoring

Both at the Czarna and Płachty Stare station (Figures 6.1 and 6.2) the RC-12 recorders (manufactured by Trax Electronik from Krakow, Poland) are installed. These recorders allow to control the connected sensors, the time step of measurements, determining the calibration curves of the sensors and collect the measured data in the internal memory. Data collected by the recorder, are transmitted via GPRS to the stations website (Figure 6.3). It is possible to copy data from remote loggers using special software or directly using a direct connection of portable computer to the recorder.

Hydrological monitoring is the most extensive part of the system. At the Czarna station the water stages are measured by using of hydrostatic pressure sensors based on pressure transducers. Two sensors of the water level from different companies SEBA and APLISENS, powered from mains and connected to the transmission system have the automatic compensation of atmospheric pressure. Inside the cables connecting the sensor to the registers, the dotted thin tube is placed, connecting the sensor with air and atmospheric pressure so the compensation is done automatically. Currently, the mechanical measuring of water levels has been terminated. In addition, for control purposes and to backup against data loss, the Czarna Station is equipped with independent from transmission system and power, Diver type sensor for measuring the hydrostatic pressure and water temperature. This device has length of about

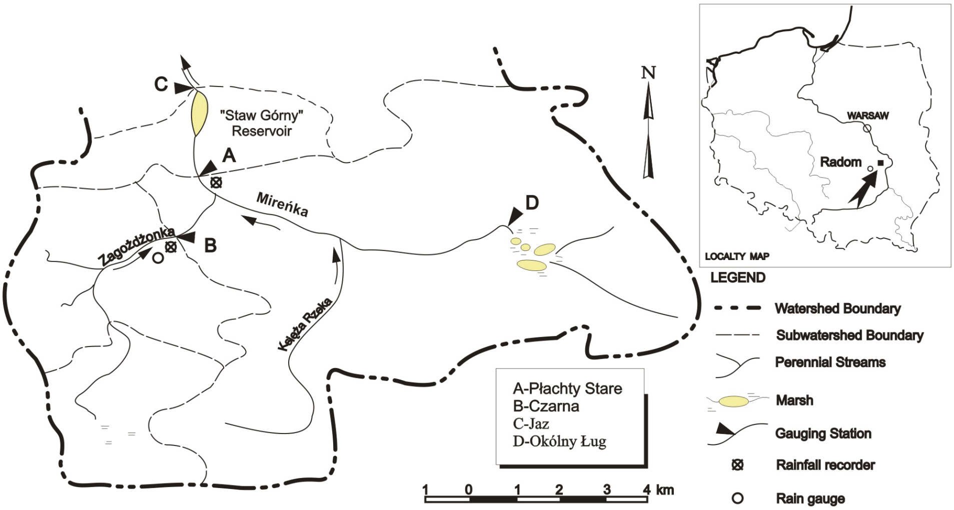
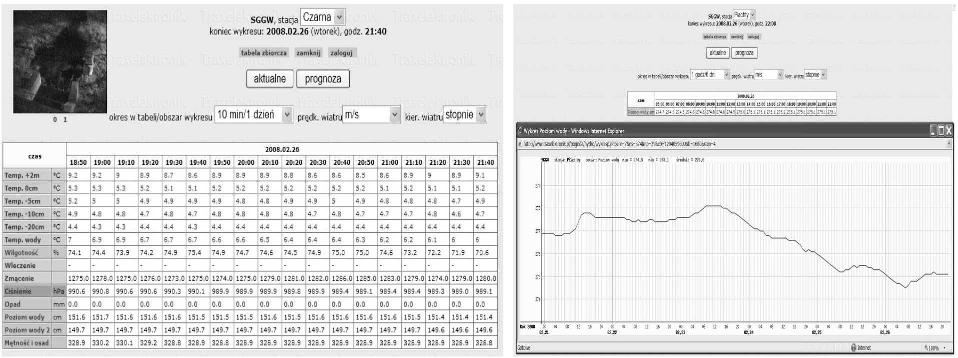


FIGURE 6.1. Locality of Zagożdżonka experimental catchment

FIGURE 6.2. The view of Czarna and Płachtach Stare gauging stations (photo L. Hejduk)



czas		2008.02.26																	
		18:50	19:00	19:10	19:20	19:30	19:40	19:50	20:00	20:10	20:20	20:30	20:40	20:50	21:00	21:10	21:20	21:30	21:40
Temp. +2m	°C	9.2	9.2	9	8.9	8.7	8.6	8.9	8.9	8.9	8.8	8.6	8.6	8.5	8.6	8.9	9	8.9	9.1
Temp. 0cm	°C	5.3	5.3	5.3	5.2	5.1	5.1	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.1	5.2	5.1	5.1	5.2
Temp. -5cm	°C	5.2	5	5	4.9	4.9	4.9	4.9	4.8	4.8	4.9	4.9	5	4.9	4.8	4.8	4.8	4.7	4.9
Temp. -10cm	°C	4.9	4.8	4.8	4.7	4.8	4.7	4.8	4.8	4.8	4.8	4.7	4.8	4.7	4.7	4.7	4.8	4.6	4.7
Temp. -20cm	°C	4.4	4.3	4.3	4.4	4.4	4.3	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Temp. wody	°C	7	6.9	6.9	6.7	6.7	6.7	6.6	6.6	6.5	6.4	6.4	6.4	6.3	6.2	6.2	6.1	6	6
Wilgotność	%	74.1	74.4	73.9	74.2	74.9	75.4	74.9	74.7	74.6	74.5	74.9	75.0	75.0	74.6	73.2	72.2	71.9	70.6
Wleczenie		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zmącenie		1275.0	1278.0	1275.0	1276.0	1273.0	1275.0	1274.0	1275.0	1279.0	1281.0	1282.0	1286.0	1285.0	1283.0	1279.0	1274.0	1279.0	1280.0
Ciśnienie	hPa	990.6	990.8	990.6	990.6	990.3	990.1	989.9	989.9	989.9	989.8	989.9	989.4	989.1	989.4	989.4	989.3	989.0	989.1
Opad	mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Poziom wody	cm	151.6	151.7	151.6	151.6	151.6	151.5	151.5	151.5	151.6	151.5	151.6	151.6	151.6	151.6	151.5	151.4	151.4	151.4
Poziom wody 2	cm	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.7	149.6	149.6	149.6
Mętność i osad		328.9	330.2	330.1	329.2	328.8	328.9	328.8	328.9	328.9	328.9	328.9	328.9	328.9	328.9	328.9	328.9	328.9	328.8

FIGURE 6.3.Examples of electronic monitoring system reports (L. Hejduk)

9 cm (the size is different for different versions of the sensors and ranges from 18 to 8 cm) and is an integrated pressure, temperature sensor and recorder with its own internal batteries. The programming of the sensor is by plugging it into a portable computer through a special optical port. Programming and data management is possible by connecting to a computer using dedicated software. The device has no pressure compensation so in order to obtain the actual state of water the atmospheric pressure compensation program is required. It can be done by subtracting receive data from the atmospheric pressure measured at the same time via a sensor type Baro-Diver.

Diver-type meters are also located on the edge of the valley close to Czarna station to control the groundwater level variation. Four piezometers are placed in a cross right on the shore at a distance of 35 meters and 94.6 meters and gauges patch on the left side within 13 and 62 meters from the patch gauges. In order to convert water levels to the corresponding flow rate the rating curve is determined for the sharp edge weir at Czarna station. Rating curve is verified by measuring the flow rate using the current meters. The system for monitoring water stages at Płachty Stare station consists of one Diver sensor as well as sensor connected to a data transmission system. Additional elements control the water velocity and flow rate are installed ISCO AV 2150 where the flow is calculated based on direct measurement of the average velocity using the Doppler effect and the measurement of water levels by measuring the hydrostatic pressure by a differential pressure transducer. One such device is installed at the Czarna station, one close to the bed load trap and one at the Płachty stare station.

The monitoring of water quality control is organized for indicators related to the potential pollution that may occur in farming areas. So, focus has been on nutrient transport monitoring. At both measuring stations the multi-parameter water quality probe Hydrolab are installed. Equipment for measuring water quality are not connected to a data transmission system. These labs have their own battery power and the configuration used at the stations provides measurements: turbidity (transport of suspended sediment), concentrations of nitrate and ammonium nitrogen, redox potential, dissolved oxygen and conductivity. In addition, at Czarna Station the device (spectrophotometer) to enable automatic measurement of concentrations of dissolved phosphate and total phosphorus (Sigma Phosphax Hach Company) is installed.

Impact of sampling time step on nutrient load calculation on the example of dissolved phosphorus – Hydrolab data from Czarna station

The time step of load calculation can have the significant impact of total load calculation. It is not known when maximum concentration will happen, so the usual schema follows the water stage measuring rules it means: once a day at 7:00 or 19:00 when the water stage at 7:00 are above certain threshold. Let's assume that we gather data from one week with the 10 minutes time step (Figure 6.4) in case of the dissolved phosphorus concentration and discharge.

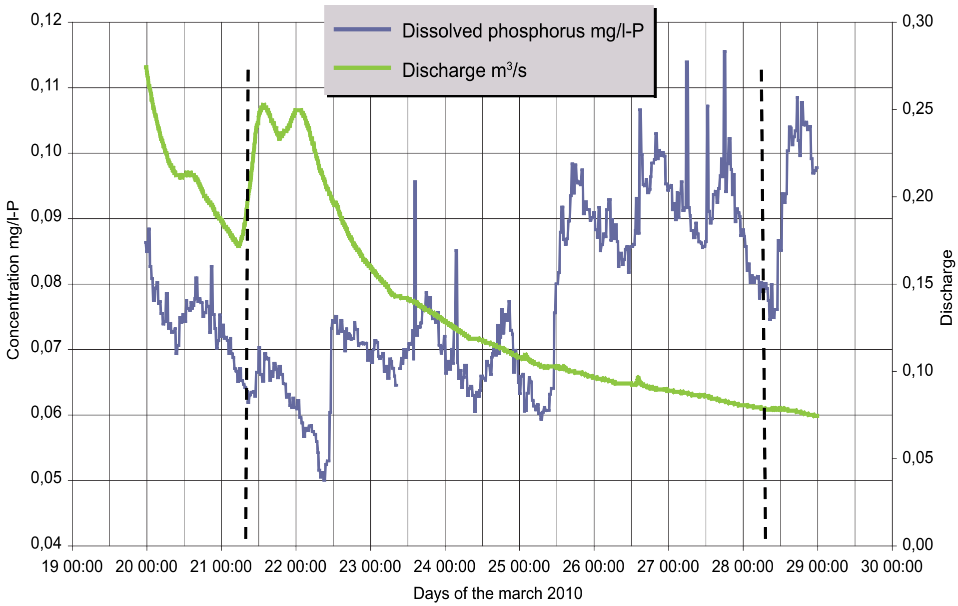


FIGURE 6.4. One week data of concentration and calculated load for Czarna station

Depending on exact time of sampling the total calculated load for the week can differ. For example, the Table 6.1 present calculation of load in 4 cases. First case represent the situation when the 10 minutes time sampling is taken into consideration and load is calculated by multiplying the discharge during the sampling by the concentration. The second case assumes that the samples are done at 7:00 every day and the load is calculated by multiplying average discharge between the two samples. The third case is similar to the second but the samples are taken at 19:00. The last case assumes, that the loads are calculated as a multiplication of 7 day average concentration of discharge. The Figure 6.5 shows the representation of the assumptions.

In this case the results received from particular assumptions lead to over/underestimation of dissolved phosphorus loads in comparison of 10 minutes data. Of course,

TABLE 6.1. Calculation of the dissolved phosphorus load during one week based on Hydrolab data from Czarna station

Sampling assumption	Load (kg/7 days)
10 minutes data	5.8
One sample 7:00	5.4
One sample 19:00	6.4
7 days average	6.1

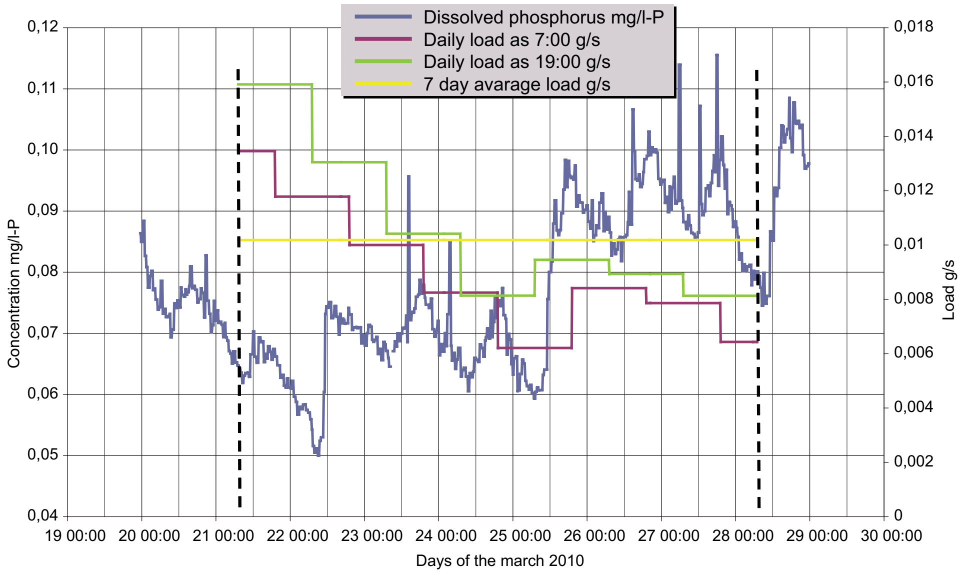


FIGURE 6.5. The graph representation of load calculation assumption

the loads depend strongly not only the concentration but on the flow. So, the high flow during high concentration has a strong impact on results. On the other hand, in case of stabile contamination the high flow lowers the concentration due to dilution phenomenon. This case can be seen on Figure 6.4 during relatively high flow.

Discharge measurement and water sampling in Norway

Agriculture is one of the main contributors of nutrients and soil to the open water and groundwater systems. The main objective of an agricultural monitoring program is to document and provide information about the actual losses and what the effects of different measures might be on the reduction of these losses. When designing the system it is important to have a clear understanding how this information should be obtained and disseminated to the local and national environmental authorities. Different aspects have to be considered when designing the monitoring system. It is important to take into consideration additional uses of the collected data for example for research purposes, the available budgets and the duration of the monitoring period. In case the collected data are used for research purposes, special requirements might be considered concerning the data collection. Another important aspect to be considered is whether the monitoring system should provide information about concentrations of nutrients and suspended solids or about total loads to the recipients. Also information and insight in the hydro-geological settings, agricultural practices and climate are important in the design. For example, agricultural catchments, characterized by event-flow exclude certain types of monitoring systems. Once the decision on the layout of a monitoring system has been made, the necessary routines for data collection, analyses and reporting can be made (Figure 6.6).

This part describes the Agricultural Environmental Monitoring Program (JOVA) in Norway presenting a description of the design and the structure of the program, various activities and routines that are applied. In addition, a summary of some major results in terms of hydrological characteristics and measured nutrient and soil loss will be presented. The JOVA-program also includes a component dealing with monitoring of pesticides, but this component is not described further in this paper.

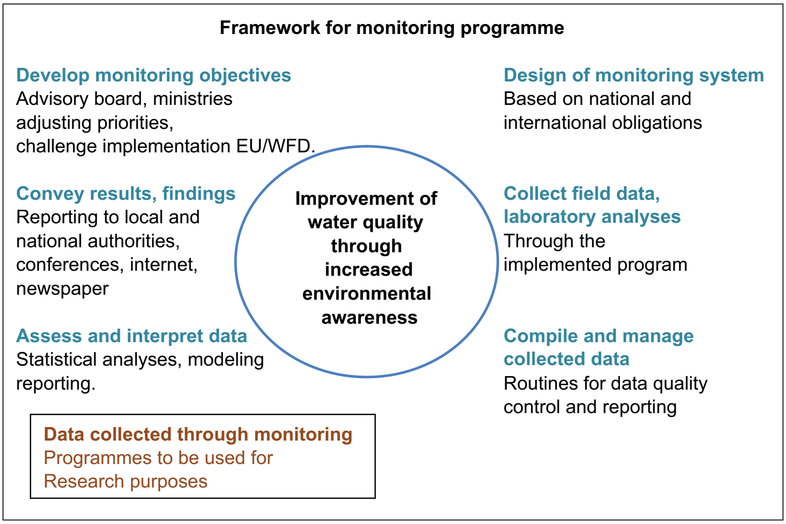


FIGURE 6.6. Monitoring framework for agriculture

The Program was established in 1992 and is an important part of the overall strategy for sustainable environmental development in Norway. One of the major and concrete objectives of the program is to quantify and to document the diffuse nutrient losses from representative agricultural areas and production systems in different agro-ecological regions of Norway, and furthermore, to help generate adequate data and knowledge for policy support and for the implementation of appropriate environmental measures. Bioforsk is in charge of the implementation of the program. Through the JOVA-program significant experience has been obtained which has been used in the development of similar monitoring programs in Estonia, Latvia and Lithuania. These programs were established in close co-operation between Bioforsk and different research organizations in the Baltic countries. More information about the programs can be found in Vagstad et al. (2001). The JOVA-program also provides high quality data which in can be used for research projects and the calibration/testing of models for the simulation of nutrient and soil loss (Deelstra et al. 2010).

Structure of the monitoring program

The program is carried out in 10 small agricultural catchments varying in size from 1–20 km^2. The catchments represent different geo-hydrological conditions, agricultural practices and climatological conditions (Table 6.2 and Figure 6.7). Three of the catchments are dominated by cereal production, four by grass production/livestock husbandry while two are characterized by a combination of cereal/grass production (with cereal as the dominating crop). One catchment has a combination of

TABLE 6.2. Main catchment characteristics

Catchments	Total area (ha)	Farm land (%)	Temp (°C)	Precip. (mm)	Soil type	Major crop
Skuterud	449	61	5.5	785	Silty loam	Cereals
Mørdre	680	65	4.3	665	Silt and clay	Cereals
Kolstad	308	68	4.2	585	Humic loam	Cereals
Hotran	1940	58	5.3	892	Silty loam/clay	Cereals, grass
Naurstad	146	35	4.5	1020	Bog/fine sand	Grass
Skas-Heigre	2930	85	7.7	1180	Clay/sand/gravel	Grass, cereals
Volbu	168	41	1.6	575	Silty sand	Grass
Vasshaglona	65	62	6.9	1230	Sand	Vegetables, potatoes, cereals
Time	1140	85	7.2	1189	Silty sand	Grass

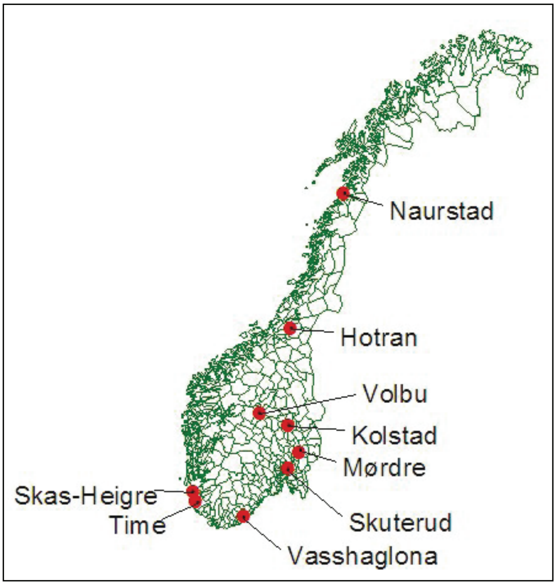


FIGURE 6.7. Geographical location of monitoring stations (above), the Mørdre catchment outlet (right, top) and Naurstad during winter (right, bottom)

potatoes, vegetables and cereals. The core data collection consists of three main components:

- Runoff measurements combined with water sampling at the main catchment outlet,
- Water quality data obtained through the water sampling program and
- Information on farm and field practices obtained by annual field surveys carried out at the level of the individual farmer field.

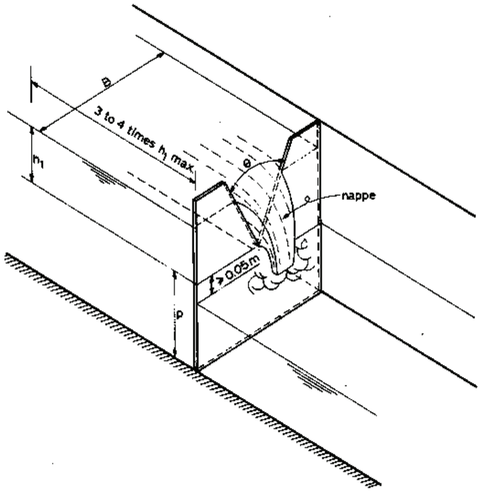
For many JOVA catchments, some climatological data are collected at the monitoring stations (air-, water temperature, precipitation) but for most of the catchments additional meteorological stations located nearby are obtained. Information about soils (type and soil physical information) is obtained from the Norwegian Institute for Forest and Landscape.

Methodological aspects

Measuring soil and nutrient losses at catchment scale is not necessarily a straightforward task. The choice of methodology regarding the accuracy and precision of the collected data has to be a compromise between costs (e.g. equipment and operation & maintenance costs) and end-users demand (e.g. researchers, managers, public authorities). In environmental monitoring there is no specific method which can be recommended. The dimensioning and structuring of an environmental monitoring program for agricultural dominated catchments has to be considered on the basis of the site specific conditions like catchment size, topography, channel characteristics, climatological conditions and the geo-hydrological settings. Correct measurements of nitrogen (N) and phosphorus (P) losses (loads in surface waters at catchment scale) require reliable and precise data on concentrations as well as on water discharge.

Discharge measurement

Different methods can be used to obtain information about stream discharge but they are often based on the combination of direct measurement of the water level and a known head-discharge relation for the measurement location (Deelstra and Øygarden 1998a). When initiating a long term monitoring programme, fixed measuring devices are preferred with a known head-discharge relation and high accuracy in discharge measurement. In the JOVA-program, both the V-notch and the Crump weir are used. The V-notch (Figure 6.8) is a widely used measurement structure in the Nordic countries (Granholm et al. 1989). When soil erosion is present, sedimentation can cause serious problems for the proper functioning of the V-notch. The Crump-weir (Figure 6.9) is a short crested weir (Bos 1978) and is extensively used in the JOVA-program. It can operate under partly submerged flow conditions while in addition it has the ability to transport sediments over the crest.



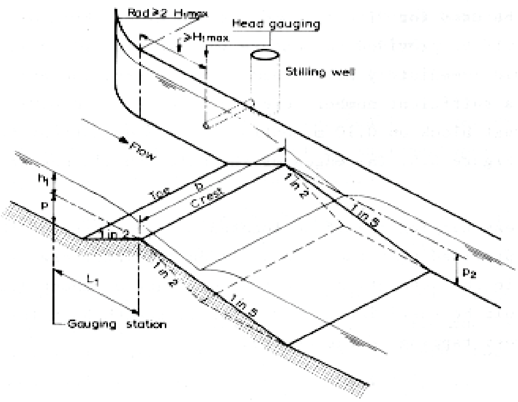
The head-discharge relation, developed in the laboratory is:

$$Q = C_e \times \frac{8}{15} \times \mathrm{tg}\alpha \times \sqrt{2 \times g} \times h_e^{2.5}$$

where:

C_e – discharge coefficient,
α – angle of V-notch,
g – acceleration of gravity,
h – water level.

FIGURE 6.8. V-notch



The head-discharge relation is:

$$Q = B_c \times C_d \times C_v \times \frac{2}{3} \times \left(\frac{2}{3} \times g\right)^{0.5} \times h_1^{1.5}$$

where:

C_d – discharge coefficient,
C_v – approach velocity coefficient,
B_c – width of structure,
g – acceleration of gravity,
h_1 – water level.

FIGURE 6.9. Crump weir

Within the JOVA-program, discharge measurements are carried out automatically based on the known head-discharge relation of the measurement structure in combination with a data-logger. At all catchments data loggers in combination with pressure transducers are used to measure the water level, while the discharge is calculated on the basis of the known head-discharge relation for the measurement structure. The data loggers used are programmable and thereby capable of steering the water sampling. The recorded data is stored in the logger and via telecommunication systems downloaded to the data control centre at Bioforsk. Before entering the data into a permanent database, several checks and controls are carried out to guarantee good quality data.

In almost all cases the monitoring station is connected to the main electricity system to guarantee continuous operation. However, electricity supply is also very necessary for those stations exposed to severe winter conditions in which case heating elements are provided to safeguard a continuous ice-free operation of the monitoring station.

Water sampling and water analysis

The selection of the appropriate water sampling strategy is an important issue in catchment monitoring programmes (Deelstra et al. 1998b). The water sampling strategy has to be able to cope with the dynamics involved in the loss generating flow processes. The losses of P, and to a lesser extend N, are typically event based, and depend on a combination of the prevailing geo-hydrological settings, climatological conditions and agricultural practices. In general one can differentiate between two sampling strategies i.e. 1) grab or "point" sampling and 2) volume proportional composite sampling. Also a combination of the two sampling strategies can occur, being point sampling during stable, low flow periods and volume proportional composite sampling during certain storm events. Comparative studies of different sampling strategies in the Nordic countries revealed substantial differences in calculated loads depending on the method used (e.g. Rekolainen et al. 1991; Kronvang and Bruhn 1996; Deelstra and Vagstad 1996; Deelstra et al. 1998b; Haraldsen and Stålnacke 2002). The general conclusion is that point sampling strategies tend to lead to erroneous estimates, particularly for the P losses. Eggestad et al. (1994) compared different grab sampling routines and found large deviations from the "true" load, calculated on the basis of volume proportional sampling. Weekly or forth-nightly sampling resulted in severe underestimated P – loads (< 10% of the "true" figures) as well as severe overestimates (more than twice the "true" figure). The deviations of N were generally less than for P. One should, however, bear in mind the prevailing geo-hydrological conditions in the Norwegian catchments, with a low base flow component in the total runoff volume in addition to many event flow situations of rather short duration. In the JOVA-program, composite water samples are collected on a volume proportional basis at all the monitoring stations. The water sampling routine is steered by a data-logger. Each time a certain volume of water has passed through the discharge measurement structure, a pre-set water sample volume is taken. The water sampling frequency is determined by the discharge intensity. The composite water sample is stored in a refrigerator at the monitoring site and collected every fortnight being subsequently analysed for N_{tot}, $NO_3 + NO_2$, P_{tot}, PO_4, susp. solids, loss on ignition, pH, EC and turbidity. The total nutrient load and soil loss is obtained on the basis of the total runoff volume and the concentration in the runoff water. The loss from the catchment (L) can in principle be calculated as the summation over time of the discharge (q_t) multiplied with the concentration (c_t):

$$L = \sum_{t=t_1}^{t=t_n} (q_t \times c_t)$$

The main reason for collecting volume proportional water samples is due to the hydrological behaviour in the catchments. The hydrological behaviour in i.e. JOVA catchments is presented in a report prepared by Deelstra et al. (2007). This is also described in more detail for the Skuterud catchment in the chapter "Comparison of hydrology in some selected catchments in Poland and Norway with focus on dominating flow paths and time resolution", by Deelstra and Banasik in this book. A disadvantage of volume proportional water sampling which is often mentioned is the fact that no information about the variation in concentration is obtained during the time period the volume proportional water sample is taken. It is a well known fact that concentrations can vary over short time periods in small agricultural dominated catchments in Norway (Eggestad et al. 1994). However, information about these variations can be of use in understanding the processes behind the nutrient – and soil loss processes. More and more sensor techniques are used to obtain this information, as is shown for the Polish catchments earlier in this chapter, and this is also the case for Norwegian catchments In the Skuterud catchment, for the last two years, a turbidity sensor has been installed and is tested for its suitability to provided reliable information about the loss of suspended solids. In this case the turbidity sensor is calibrated against the actual concentration of suspended solids in the stream by taking grab samples. Recently also the testing of a nitrate sensor has been started. Preliminary results show large variations in turbidity over short time periods, an example of which is shown in (Figure 6.10).

As can be seen, there is a large variation in the turbidity over very short time periods with changing discharge. Sampling routines based on grab sampling would lead to values for load quite different from reality while at the same time different grab sampling routines (every week, every second week or monthly) can lead to quite different results. The big advantage of sensors is the possibility to study in more detail the processes behind soil loss. Of course many other data are needed but it is felt that in the JOVA-program the secondary data collection, i.e. information on farming practices (see the next subchapter), climatological data and soil data will be of great use to improve our knowledge about soil and nutrient loss processes.

Information on farm and field practices

For the majority of the catchments in the JOVA-program, information on farming practices are available on an annual basis. Through yearly questionnaires, the farmers provide information on management practices for the individual farmer fields within the catchment. These data consist of planting (crop and time), nutrient application (time and rate), soil management, pesticide use (time and rate) and yield

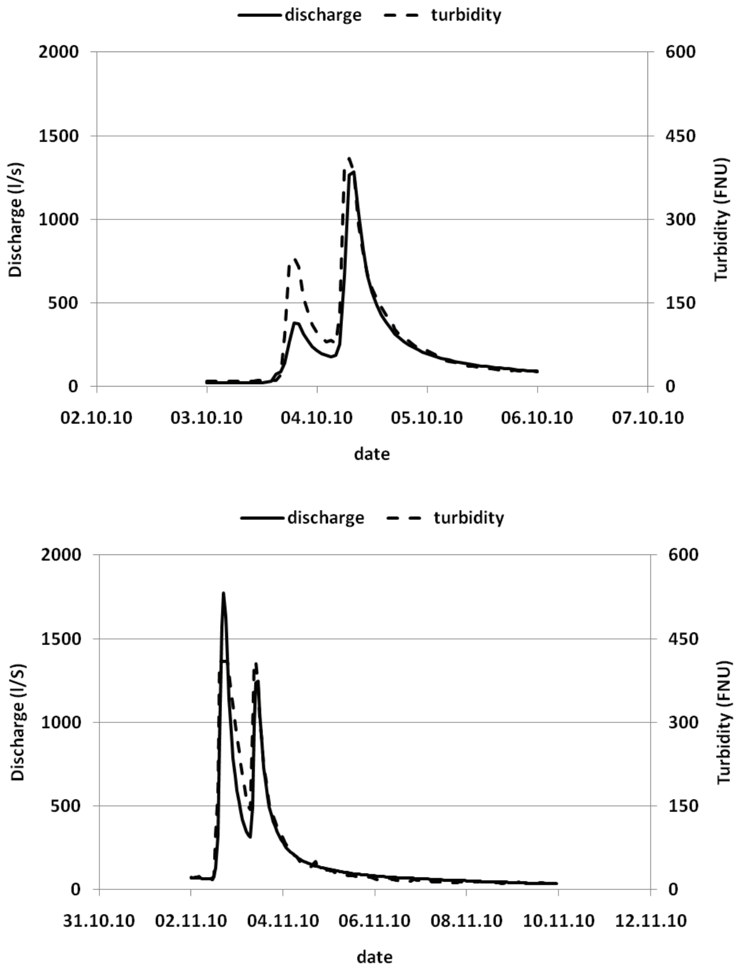


FIGURE 6.10. Discharge and turbidity for the Skuterud catchment for two different periods in 2010

(time and amount). The farmer field scale is a management unit and varies in size from < 1 – 20 ha, with an average size of 2.3 ha. These data are stored in a database from which standard output files are available for the yearly reporting as well as data for more specialized data analysis. The database contains standard values for nutrient contents of crops and fertilizers for calculation of e.g. nutrient balances. Figure 6.11 gives an example of the use of farmer information, presenting the soil condition on the individual farmer fields during an autumn period.

For some of the larger catchments in the JOVA-program, the information on agricultural practices consists only of data from Statistics Norway. Data from Statistics Norway contain information on distribution of crops, soil cultivation, and livestock

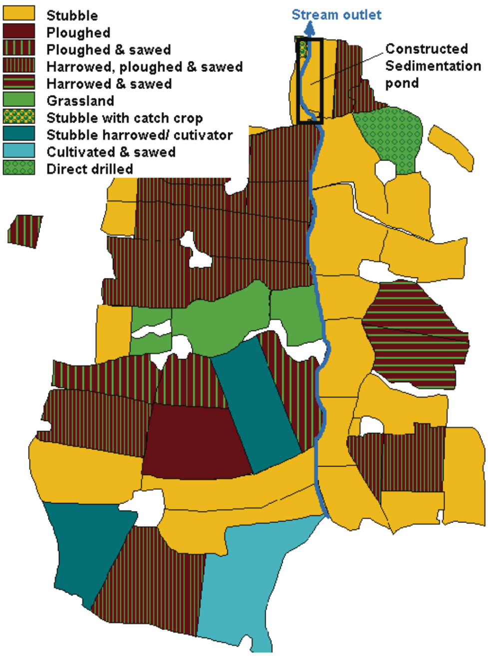


FIGURE 6.11. Soil conditions during autumn on fields in the Skuterud catchment

density for all years and nutrient application (time and rate) for some years. Contrary to the data collected through the yearly questionnaires, the data from Statistics Norway are only available at farm scale.

Conclusion

There are differences between monitoring systems in Norway and Poland as presented here. Each country conducts the monitoring in a different way and scale, but there are similarities.

In Norway the V-notch weir is used when there is no problem with sediment transport. In case of Czarna station in Poland the V-notch weir has been introduced as well, but there is a sediment accumulation problems so the weir has to be cleaned every year. It should be considered to change the weir type to avoid slitting problems.

To avoid the freezing of the measuring devices, the heating is applied during winter in Norway, in this case providing continuous discharge measurements and water sampling. Such a solution in not used in Poland. If the weir froze during winter, there is a gap in the data.

There is a significant difference between sampling method in Norway and Poland for nutrient concentration and load estimation. The volume proportional system is used in Norway and the point or grab sampling in Poland. Both methods have their advantages and disadvantages.

In case of nutrient monitoring, it is very important to have the data base, which contains information about inter alia crops rotation, fertilizers application. The Norwegian database can play role as the model for development of this type of data base in Polish condition, especially for a small catchments.

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