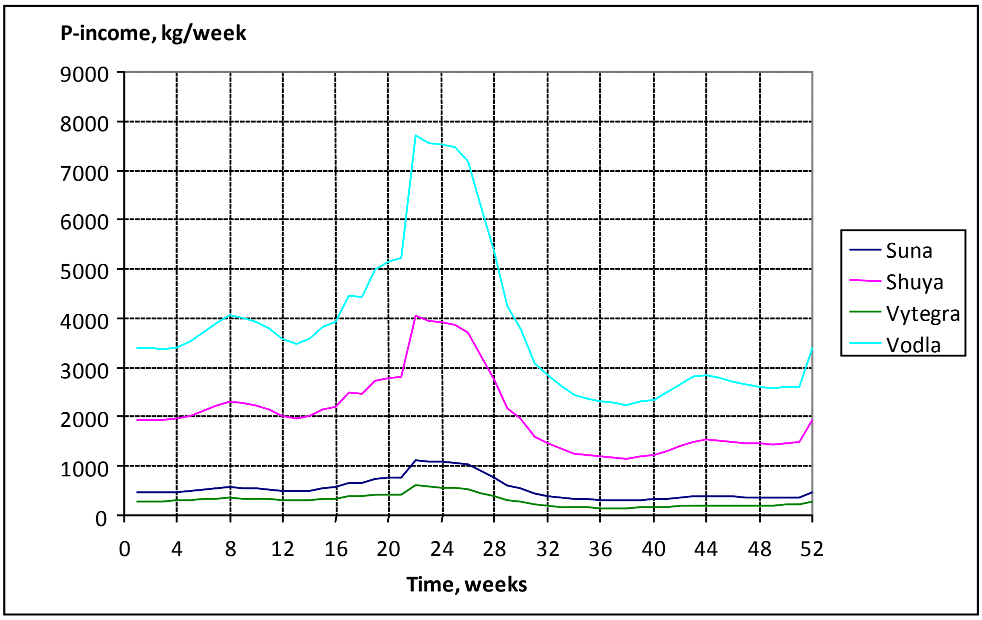

Fig. 8.3. Total P income with main inflow rivers to Lake Onega calculated using LakeWeb load sub-model.

The comparison of calculated and measured total phosphorus concentrations shows rather good agreement even in the case of default value of TP concentration 30 mg m^{-3} used for all rivers (Fig. 8.4).

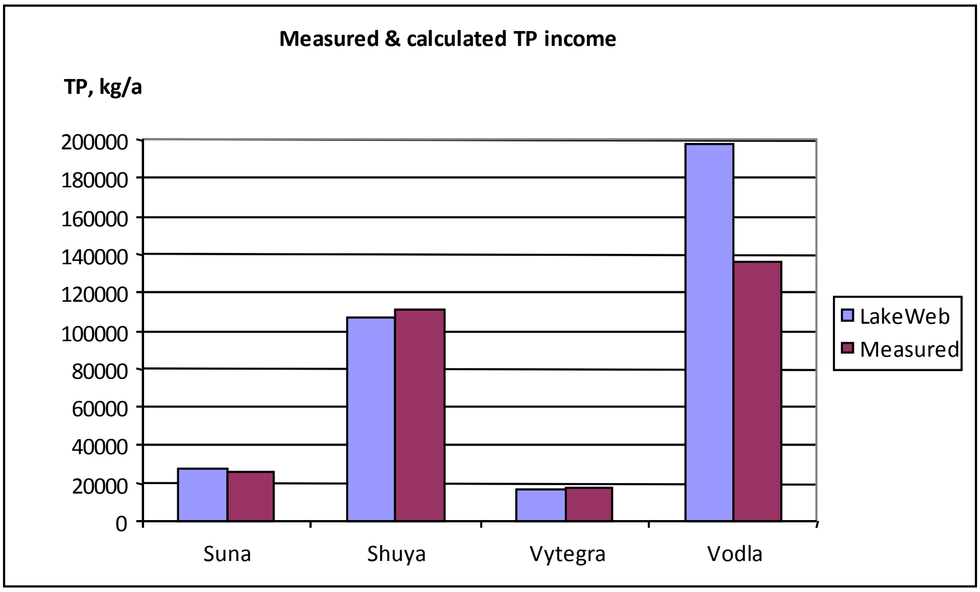

Fig. 8.4. Comparison of measured and total phosphorus income calculated using LakeWeb model for the period April 2001-March 2002 (12 months).

This simple statistical phosphorus load model was combined with Vollenweider – Canfield – Bachmann lake model (1), (3) into one integrated lake-catchment model. A graphical user interface, GUI (Figs. 8.5 - 8.6) helps to modify input parameters and to visualize the model output.

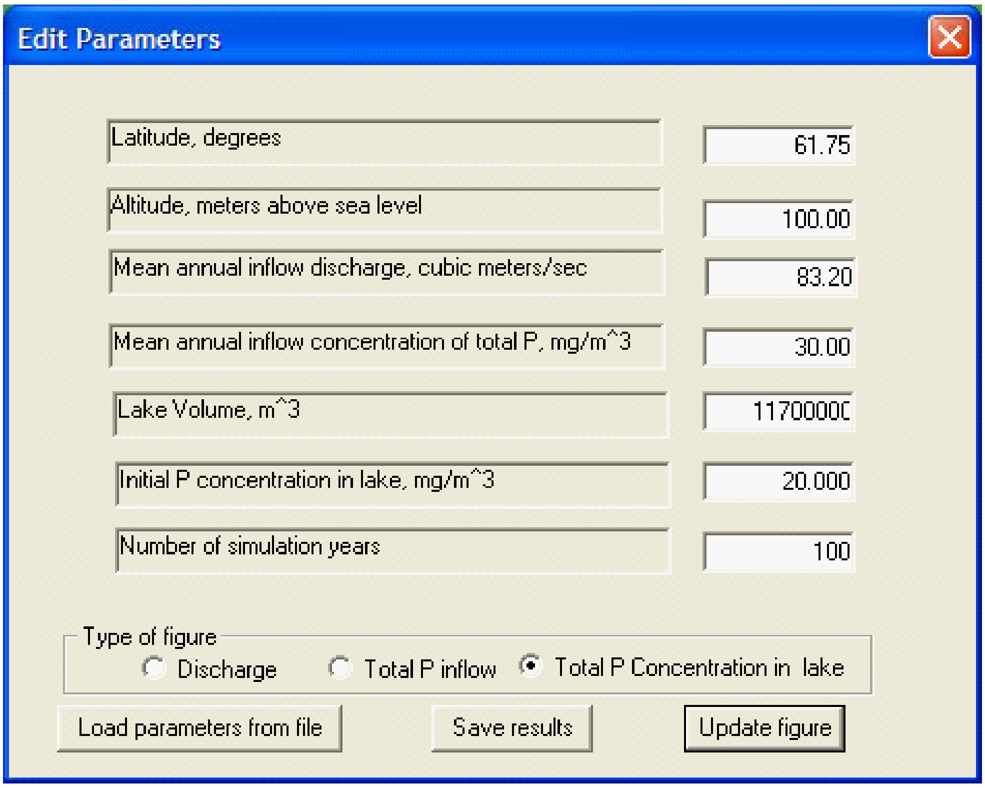

Fig. 8.5. Input parameters dialog of the integrated lake-catchment model interface.

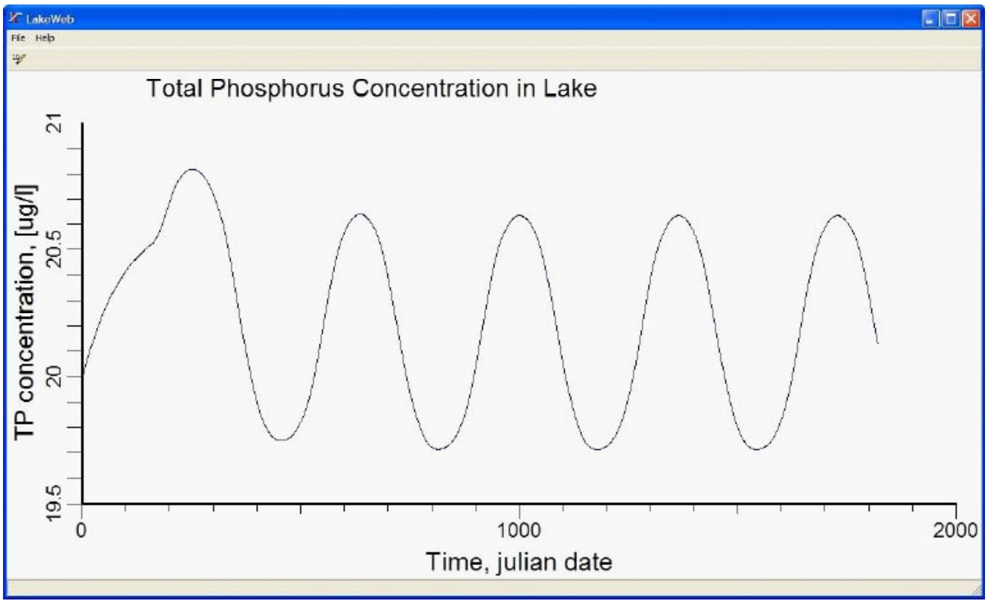

Fig. 8.6. Output window of the lake-catchment model GUI.

This model was applied to Petrozavodsk and Kondopoga Bays of Lake Onega. The calculations were organized in the following way. The model was run for several years period with different combinations of mean annual inflow discharge and mean annual inflow concentration of total phosphorus until the periodic solution was achieved. The calculated total phosphorus concentration in lake waters was averaged for the last simulated one year period. These values were tabulated and contour plots of lake TP concentration as a function of mean annual discharge and inflow TP concentration were produced (Figs. 8.7 and 8.8).

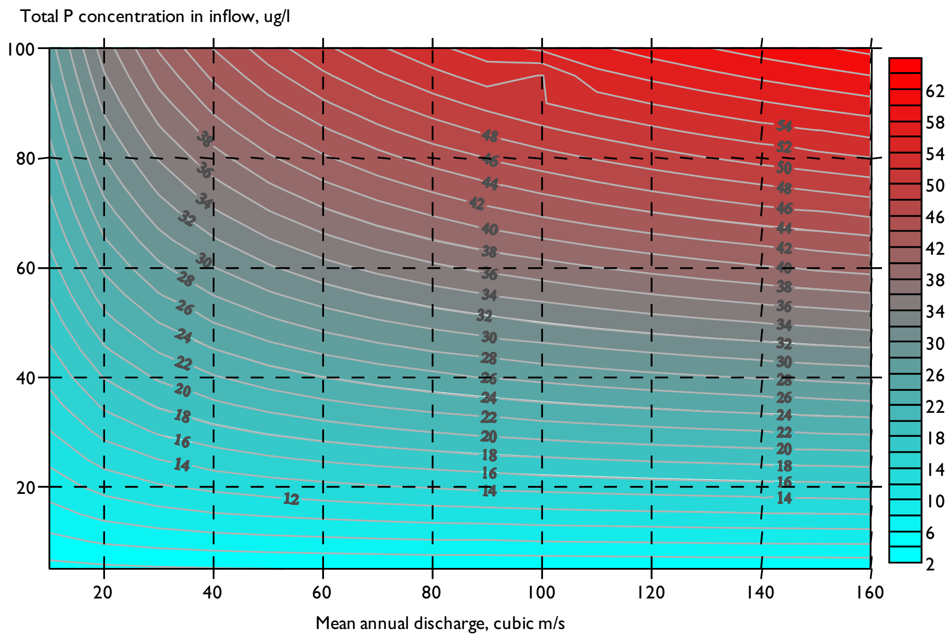

Fig. 8.7. Average annual total phosphorus concentration in Petrozavodsk Bay as a function of inflow discharge and total phosphorus inflow concentration.

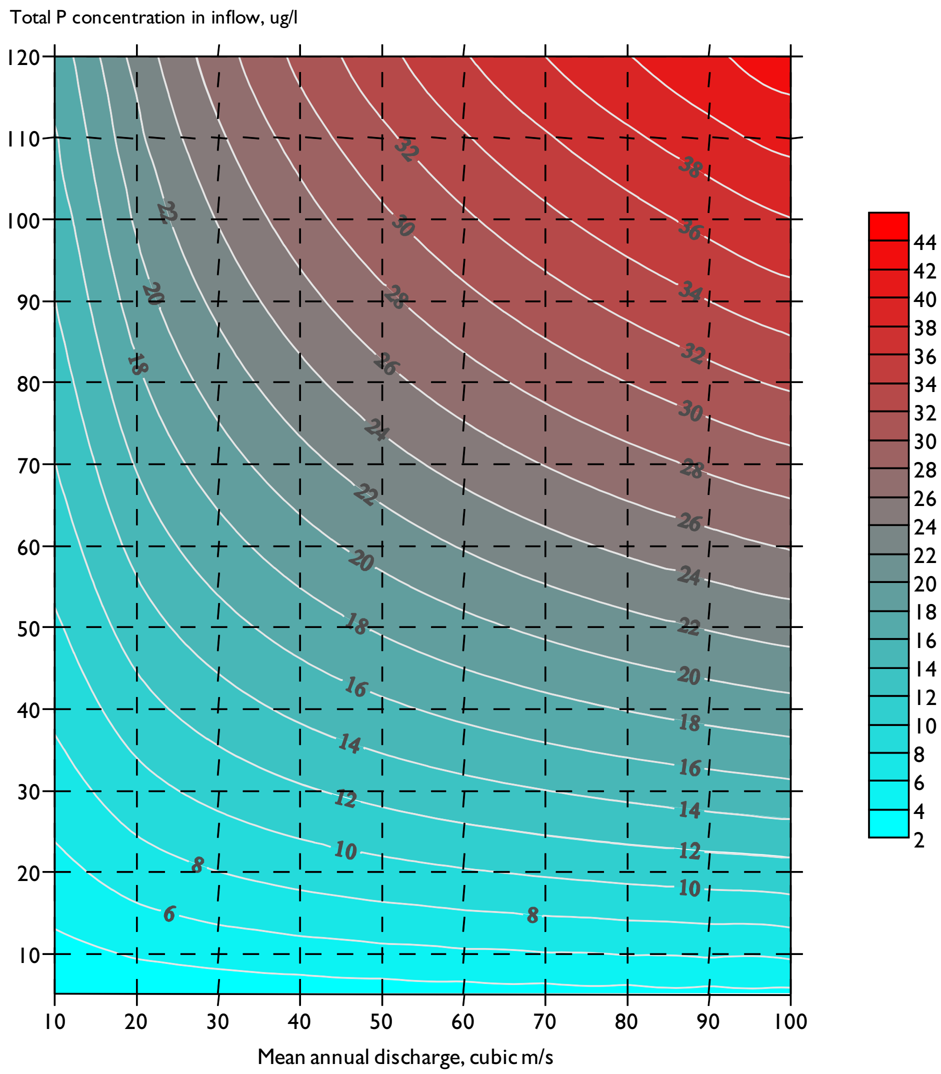

Fig. 8.8. Average annual total phosphorus concentration in Kondopoga Bay as a function of inflow discharge and total phosphorus inflow concentration.

These diagrams can be used for quick estimates of TP concentration in Petrozavodsk and Kondopoga Bays under different hydrological conditions. The whole procedure can be described as follow: using non-exceedence probability curves of River Shuya (Fig. 8.9, Petrozavodsk Bay tributary) and River Suna (Fig. 8.10, Kondopoga Bay tributary) the mean annual discharge values of specific non-exceedence probability can be obtained. Using this value and the inflow total phosphorus concentration the resulting lake TP concentration can be easily estimated from diagrams (Figs.8.7 and 8.8). Of course, the limitations of the box models should always be kept in mind when using these diagrams, but, nevertheless, it appears that this method is a useful simple approach to estimate the effects of possible changes in the system catchment-lake on in-lake TP concentration.

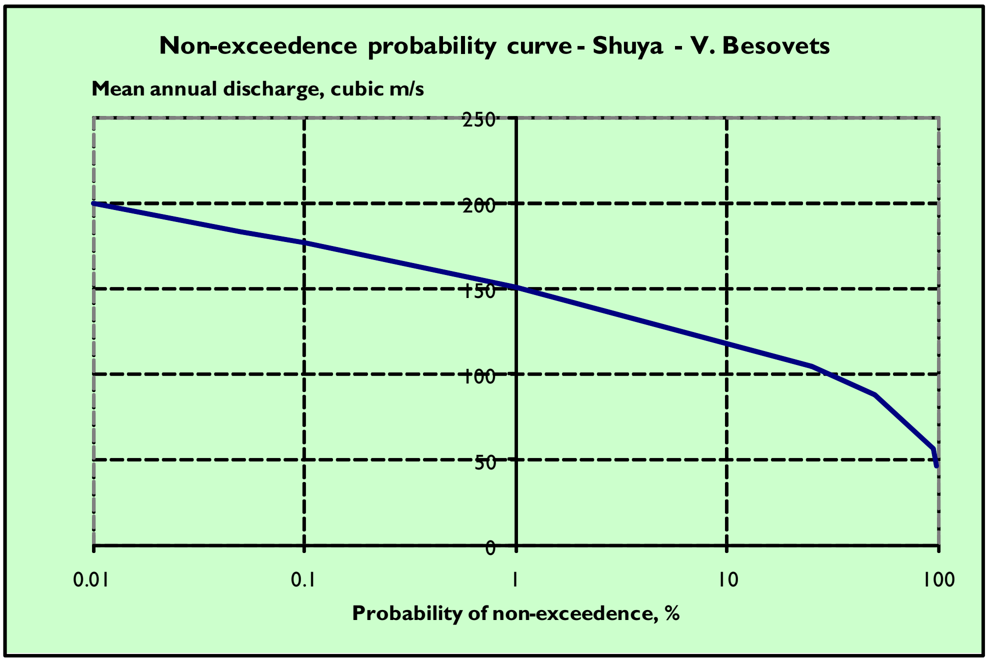

Fig. 8.9. Non-exceedence probability curve – River Shuya – V. Besovets site.

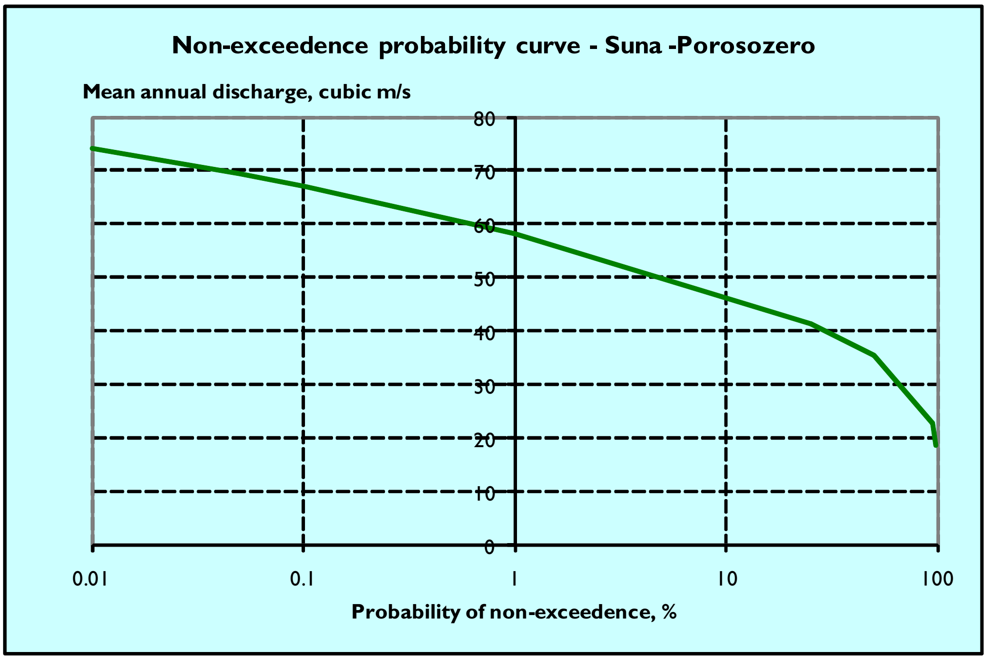

Fig. 8.10. Non-exceedence probability curve – River Suna – Porosozero site.

8.2

Application of Danish phosphorus model P2 to Kondopoga Bay

As it was described earlier the Kondopoga Bay is a receiver of wastewaters from Kondopoga PPM for more than 70 years. Every year nearly 3000 tons of suspended matter, 8 tons of oil products, 4 tons of methanol, 60 tons of P, 80 tons of N, 147 tons of chlorides, 9 tons of formaldehyde, 2000 tons of lignosulphonates are withdrawn to the bay (Belkina 2005).

The Danish model for P retention in lakes has two state variables (HELCOM 2006): P_l – total phosphorus concentration in lake water and P_s – exchangeable total P in sediments. Driving parameters in the model are: P_i – inflow total P concentration, Q – water discharge and T – lake water temperature.

$$\frac{dP_l}{dt} = \frac{Q}{V}\left(k \cdot P_i - P_l\right) - S + R,$$
$$\frac{dP_s}{dt} = \frac{Q}{V}\left((1-k) \cdot P_i\right) + S - R,$$
$$k = \frac{1}{1+\sqrt{\dfrac{V}{365 \cdot Q}}}, \tag{5}$$
$$S = a \cdot (1+C_1)^{T-20} \cdot \frac{P_l}{H},$$
$$R = b \cdot (1+C_2)^{T-20} \cdot P_s$$

Here V is the lake volume, m^3, Q – inflow discharge, $m^3\ day^{-1}$, H – lake depth, m, S – sedimentation, R – release of TP from sediments to lake water, a – sedimentation rate of TP, $g\ P\ m^{-2}\ day^{-1}$, C_1 – temperature correction for a, b – release rate of TP, $g\ P\ m^{-2}\ day^{-1}$, C_2 – temperature correction for b, T is the water temperature.

Calibrated values of parameters on the basis of data from 16 lakes (HELCOM 2006) are: sedimentation rate a=0.047, temperature dependence of P-sedimentation $C_1 = 0.0$, sediment release rate b=0.000595, temperature dependence of P- release $C_2 = 0.08$.

By introducing new parameters: A=Q/V+a/h, B=b(1+C_2)$^{T-20}$, C=Q/V*k*P_i, E= C=Q/V*(1-k)*P_i, the system of equations can be rewritten in matrix-vector form:

$$P' = M \cdot P + \begin{Bmatrix} \frac{Qk}{V} \\ \frac{Q(1-k)}{V} \end{Bmatrix} \bullet P_i,$$

$$P = \begin{Bmatrix} P_l \\ P_s \end{Bmatrix}, \qquad (6)$$

$$M = \begin{bmatrix} -A & B \\ A - \frac{Q}{V} & -B \end{bmatrix}.$$

Characteristic equation is the following:

$$\det(M - \lambda I) = \lambda^2 + (A+B)\lambda + \frac{Q}{V}B = 0 \qquad (7)$$

The eigenvalues are :

$$\lambda_{1,2} = -\frac{A+B}{2} \pm \sqrt{\left(\frac{A+B}{2}\right)^2 - \frac{Q}{V}B} \qquad (8)$$

It should be noted that both eigenvalues are negative for all combinations of parameters. For systems of order ≤ 2 this is necessary and sufficient condition of stability.

The stationary solution of the system can be obtained in the closed form:

$$P_l = P_i,$$

$$P_s = \frac{\left(\frac{Q}{V} \cdot (1-k) + \frac{a}{H}\right)}{b \cdot (1+C_2)^{T-20}} \cdot P_i \qquad (9)$$

For example, in Kondopoga Bay mean annual discharge (River Suna) Q_{Suna} equals 44.3 m^3 s^{-1}, the income of TP with river water is 28 tons a^{-1} , then mean total phosphorus concentration is P_{Suna}=0.0115 g m^{-3}. Kondopoga PPM produced 0.0529 km^3 a^{-1} of sewage waters in 1992-1996 (Filatov et al. 1999), the income of TP with sewage water was 66.5 tons a^{-1}, which gives P_{PPM}=1.2571 g m^{-3}, $P_i=(Q_{Suna}P_{Suna}+Q_{PPM}P_{PPM})/(Q_{Suna}+Q_{PPM})$= 0.0381 g m^{-3}. Then using the steady-state solution (10) we will get for lake waters P_l=0.0381 g m^{-3}, and for bottom sediments P_s=0.383 g m^{-3} at T_{water}=10 ºC.

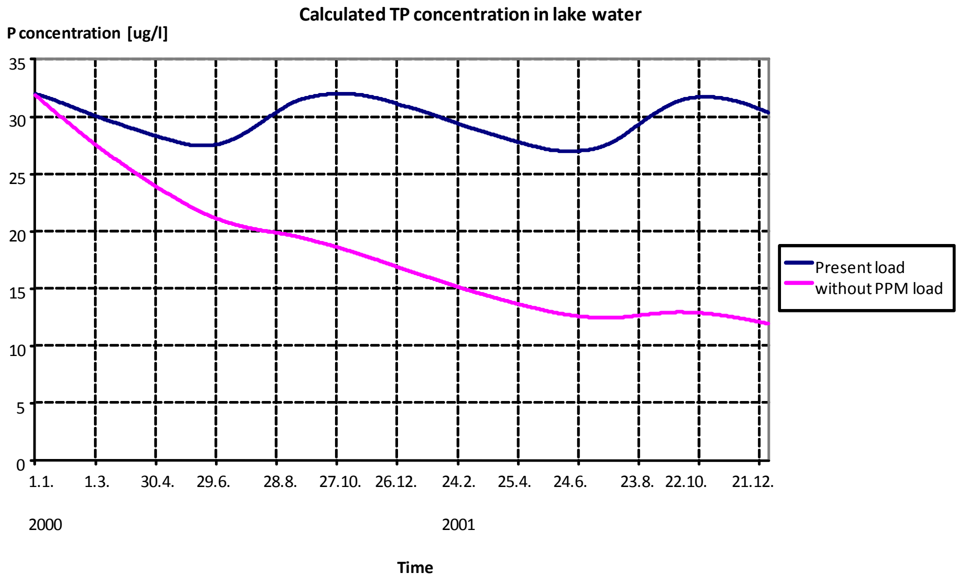

Fig. 8.11. Calculated variation of phosphorus concentration in Kondopoga Bay waters during period 2000 – 2001 with present and without Kondopoga PPM loading.

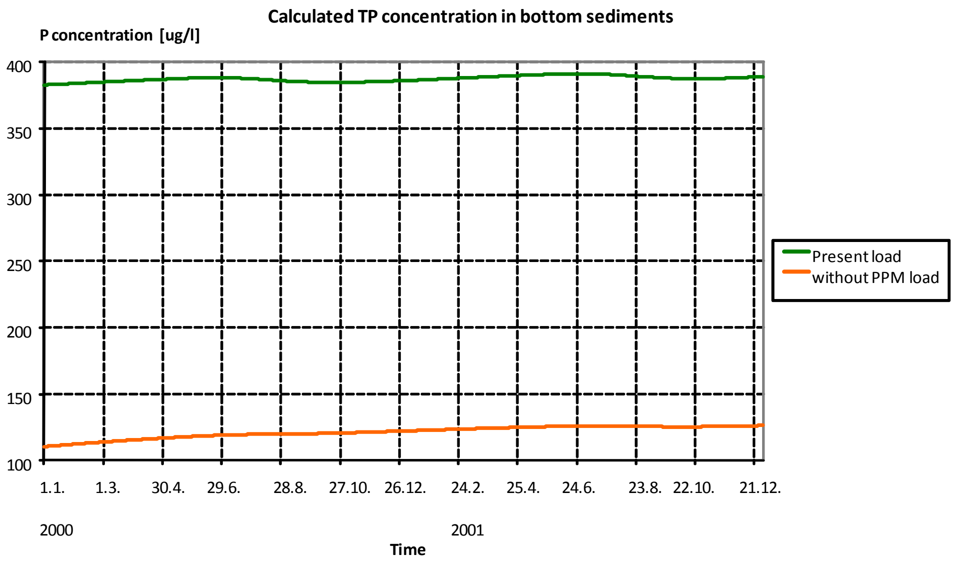

Fig. 8.12. Calculated variation of phosphorus concentration in bottom sediments during period 2000 – 2001 with present and without Kondopoga PPM loading.

Figures 8.11 and 8.12 show examples of phosphorus concentration changes with time during two years period in lake water and bottom sediments calculated with P2 model. Two cases were considered: with present loading from Kondopoga PPM (66.5 tons a^{-1}) and without industrial loading. In the latter case the inflow concentration P_i=0.011 g m^{-3}.

8.3

Aquatox model – box-type model for aquatic ecosystems

Short description of the model

AQUATOX (Park & Clough 2004) predicts the fate of various pollutants, such as nutrients and organic chemicals, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants.

AQUATOX simulates the transfer of biomass, energy and chemicals from one compartment of the ecosystem to another. It does this by simultaneously computing each of the most important chemical or biological processes for each day of the simulation period; it is a process-based or mechanistic model. AQUATOX can predict not only the environmental fate of chemicals in aquatic ecosystems, but also their direct and indirect effects on the resident organisms. Therefore it has the potential to establish causal links between chemical water quality and biological response and aquatic life uses.

AQUATOX is the only general ecological risk model that represents the combined environmental fate and effects of conventional pollutants, such as nutrients and sediments, and toxic chemicals in aquatic ecosystems. It considers several trophic levels, including attached and planktonic algae and submerged aquatic vegetation, invertebrates, and forage, bottom-feeding, and game fish; it also represents associated organic toxicants. It has been implemented for streams, ponds, lakes, limnocorrals, and reservoirs.

The fate portion of the model, which is applicable especially to organic toxicants, includes: partitioning among organisms, suspended and sedimented detritus, suspended and sedimented inorganic sediments, and water; volatilization; hydrolysis; photolysis; ionization; and microbial degradation. The effects portion of the model includes: acute toxicity to the various organisms modeled; and indirect effects such as release of grazing and predation pressure, increase in detritus and recycling of nutrients from killed organisms, dissolved oxygen sag due to increased decomposition, and loss of food base for animals.

Application to Petrozavodsk Bay and Kondopoga Bay

The AQUATOX model was applied separately to Petrozavodsk and Kondopoga Bays of Lake Onega. The model variables included several fractions of nitrogen and phosphorus, carbon dioxide, oxygen, total suspended solids, several groups of phytoplankton, zooplankton and detritus (Fig. 8.13). The main emphasis in numerical experiments was done on quantification of point-source loading effects on ecosystem dynamics. Meteorological parameters, like water temperature, light, wind speed and others control hydrodynamics, mixing conditions and light penetration. For the purpose of this study it was sufficient to use weather generator built in AQUATOX model, which is able to produce averaged dynamic weather conditions typical for given latitude and altitude. Other input parameters: lake volume, kinetic constants, initial conditions can be entered into the model with a user-friendly interface.

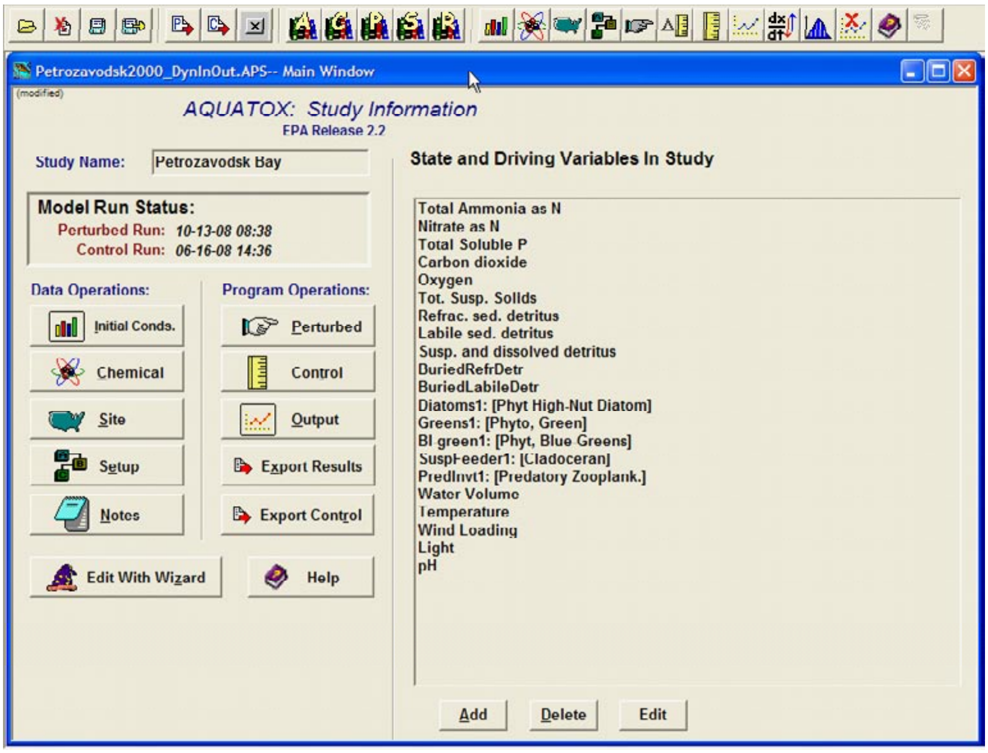

Fig. 8.13. Main interface window of AQUATOX model.

Dynamic non-point source phosphorus loading to Petrozavodsk and Kondopoga Bays was calculated using LakeWeb catchment sub-model described above and introduced to AQUATOX as input data. Since no data was available on temporal evolution of point-source loading, the constant daily loading values were used in all scenarios. Results of simulations for epilimnion of Petrozavodsk Bay are presented in Figs. 8.14 – 8.15 and for epilimnion of Kondopoga Bay – in Figs. 8.16 – 8.17. All simulations were done for three year period: 2000 - 2002. To keep the mass balance in calculations the outflow from the bays was equalled to inflow.

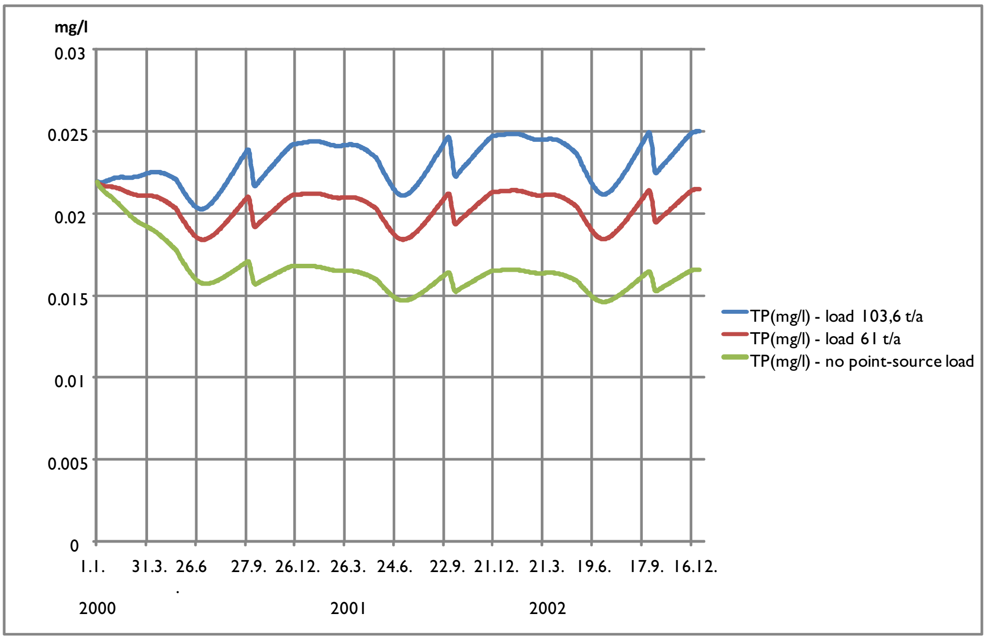

Fig. 8.14. A comparison of calculated total phosphorus concentration in Petrozavodsk Bay under different loading scenarios.

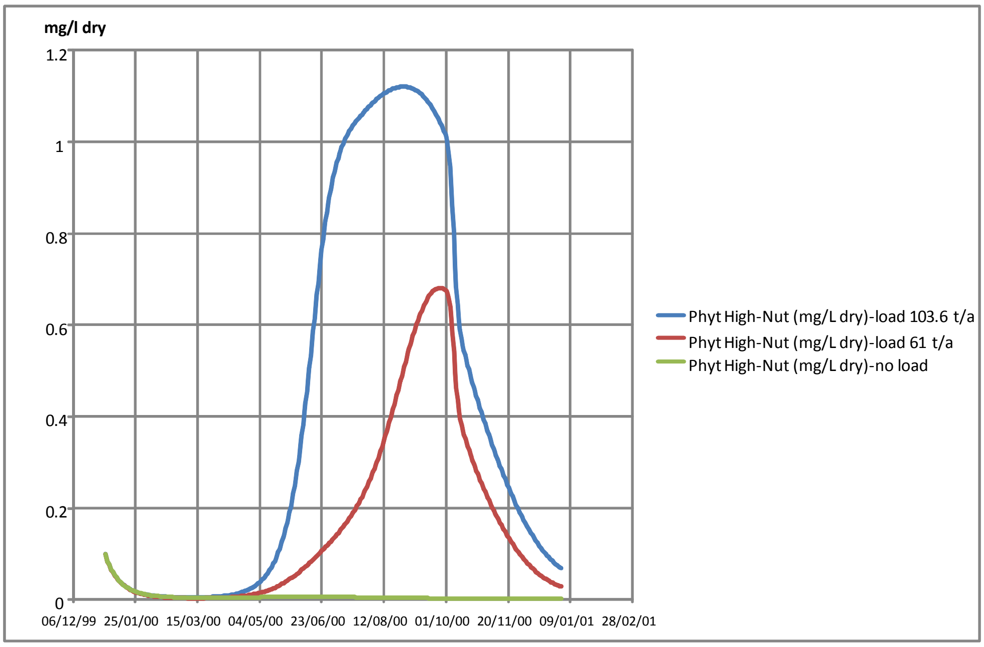

Fig. 8.15. A comparison of calculated phytoplankton biomass in epilimnion of Petrozavodsk Bay under different point-source loading scenarios.

Despite a very schematic representation of meteorological conditions and loading scenarios the models rather well simulates timing of algal blooms in the end of June - beginning of July. The influence of point-source loading is more pronounced in Petrozavodsk Bay. This can be explained by its smaller size compared to Kondopoga Bay. The calculated total phytoplankton biomass peak in Petrozavodsk Bay decreases by nearly 40% when total phosphorus loading is reduced from present 103.6 tons a^{-1} to 61 tons a^{-1} (Fig. 8.14).

Kondopoga Bay

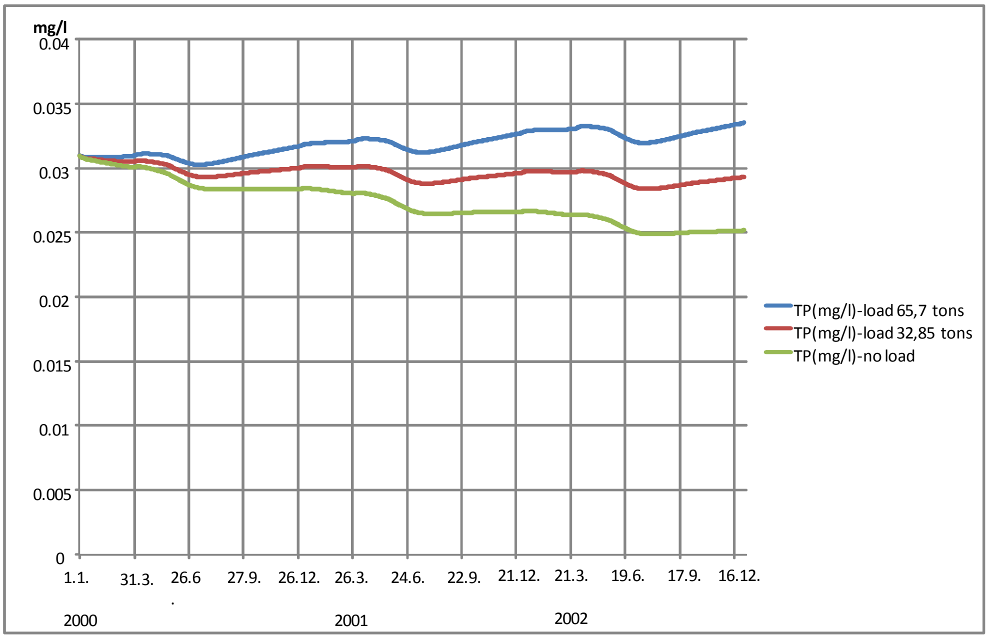

Fig. 8.16. A comparison of calculated total phosphorus concentration in epilimnion of Kondopoga Bay under different point-source loading scenarios.

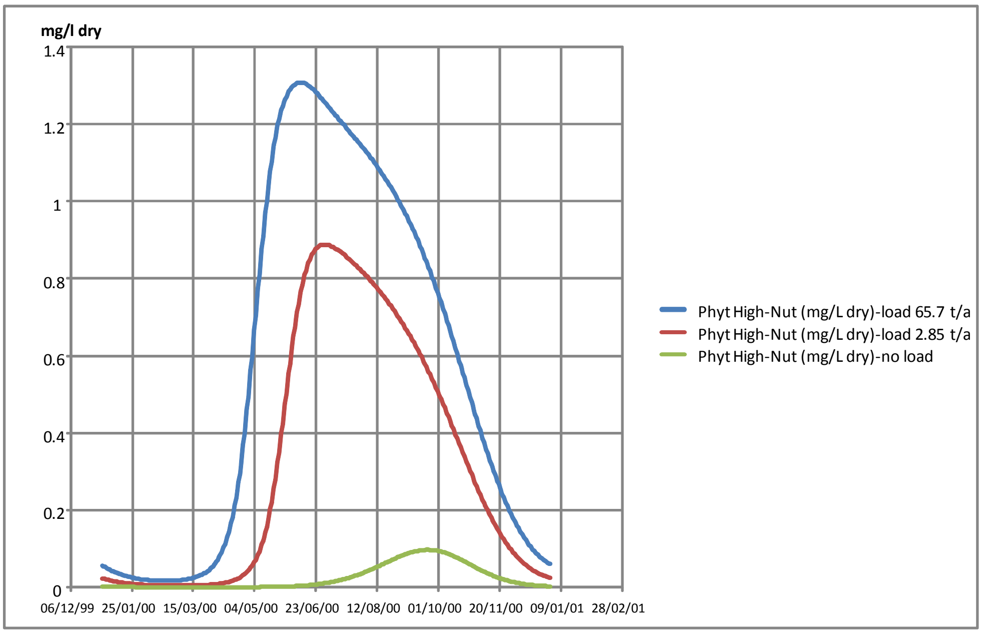

Fig. 8.17. A comparison of calculated phytoplankton biomass in epilimnion of Kondopoga Bay under different point-source loading scenarios.

9 General programme of measures

9.1

Wastewater treatment in sparse population and point source loading

Wastewater treatment is the process of removing contaminants from wastewater and household sewage, etc. runoff (effluents), domestic and industry. It includes physical, chemical, and biological processes to remove physical, chemical and biological contaminants. Its objective is to produce a waste stream (or treated effluent) and a solid waste or sludge suitable for discharge or reuse back into the environment. This material is often inadvertently contaminated with many toxic organic and inorganic compounds.

Sewage is created by residences, institutions, hospitals and commercial and industrial establishments. Raw influent (sewage) includes household waste liquid from toilets, baths, showers, kitchens, sinks, and so forth that is disposed of via sewers. In many areas, sewage also includes liquid waste from industry and commerce.

Sewage can be treated close to where it is created (in septic tanks, biofilters or aerobic treatment systems), or collected and transported via a network of pipes and pump stations to a municipal treatment plant. Sewage collection and treatment is typically subject to local, state and federal regulations and standards. Industrial sources of wastewater often require specialized treatment processes.

Conventional sewage treatment involves three stages, called primary, secondary and tertiary treatment. First, the solids are separated from the wastewater stream. Then dissolved biological matter is progressively converted into a solid mass by using indigenous, water-borne micro-organisms. Finally, the biological solids are neutralized then disposed of or reused, and the treated water may be disinfected chemically or physically (for example by lagoons and microfiltration). The final effluent can be discharged into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

The treatment of wastewaters in rural areas of Finland with no centralized sewerage system will be improved greatly over the coming years, thanks to legislation in the Onsite Wastewater System Decree, which came into force on 1.1.2004. The Decree sets minimum standards for wastewater treatment and the planning, construction, use and maintenance of treatment systems. According to Finland´s Environmental protection Act, wastewater in areas not connected to any centralized sewerage system must be treated so that it does not pollute the environment and there is no risk of pollution. The Decree stipulates that at least 90% of the organic material (BOD_7) should be removed from wastewater, as well as >85% of total phosphorus and >40 % of total nitrogen with regard to the person equivalent load defined in the Decree. Municipalities may also take local conditions into account and enforce slightly higher or lower standards in municipal environmental protection regulations where this is justifiable. The requirements in the Decree apply immediately to all new buildings, while wastewater treatment systems of buildings completed before 1.1.2004 must in most cases be upgraded to fulfill the new standards by 1.1.2014. If only very small amounts of wastewater are generated, ”grey wastewater” from kitchens and bathrooms may be simply released into the ground untreated. This wastewater may not contain toilet waste, or represent any other type of pollution risk.

Industrial wastewater treatment covers the mechanisms and processes used to treat waters that have been contaminated in some way by anthropogenic industrial or commercial activities prior to its release into the environment or its re-use. Most industries produce some wet waste although recent trends in the developed world have been to minimize such production or recycle such waste within the production process. However, many industries remain dependent on processes that produce wastewaters. Based on the review of wastewater treatment of pulp and paper mill (Pokhrel & Viraraghavan 2004), the following conclusions are drawn:

- Both aerobic and anaerobic treatment systems are feasible to treat wastewater from all types of pulp and paper mills except that bleaching kraft effluents are less suitable for treatment by anaerobic means, as they are more toxic to anaerobic bacteria.
- The anaerobic treatment of high strength wastewater requires further treatment as it contains high residual COD.
- A combination using an anaerobic process followed by an aerobic treatment system is a better option, as it can make use of the advantages of both the treatment processes.
- Color is removed efficiently by fungal treatment, coagulation, chemical oxidation, and ozonation.
- Chlorinated phenolic compounds and AOX can be removed by adsorption, ozonation and membrane filtration.
- Combinations of two or more physicochemical processes produce a high removal of toxic pollutants.
- Combinations of physicochemical and biological treatment processes with optimization of the process provide a long-term solution for pulp and paper mill effluent treatment.
- More studies are needed on the removal of AOX and chlorinated phenolic compounds.

9.2 Water pollution control methods in agriculture

Loading caused by agriculture

The phosphorus and nitrogen load caused by field cultivation is one of the most significant environmental problems deriving from agriculture. It has been estimated that the leaching of phosphorus is 0.9–1.8 kg ha^{-1} every year in Finland, and the leaching of nitrogen is 10–20 kg ha^{-1} (Rekolainen et al. 1995).

Water pollution control methods used in agriculture are listed below:

- reducing the use of fertilisers
- lighter tillage practices
- green fallowing
- reducing the use of pesticides
- subsoil drainage
- controlled drainage
- lime filter drainage
- buffer zones and strips
- sedimentation basins
- wetland areas

9.2.1
Reducing the use of fertilizers

By more precise timing of application and by using the right amount of fertilisers one can prevent the depositing of nutrients in the soil surface so that the leaching of nutrients from the fields is reduced. If the used fertiliser is manure, it has to be applied on an unfrozen field and covered soon after so that the risk of nutrient leaching is smaller. The best time to apply fertilisers is when sowing in the spring. The quality and quantity of fertilisers have to be optimised for the cultivated plant in question.
Decreasing fertilising peaks and optimising the amount of used fertilisers are basic objectives in the environmental objectives of EU's agricultural policy.

9.2.2
Controlled drainage

Description of the method
The purpose of controlled drainage is to stabilise the water management of fields and to reduce irrigation of and runoff from fields. The basic principle of controlled drainage is to keep the groundwater level as high as possible to enable cultivation. The drainage system is in this case completely under water. During heavy rainfall and harvesting the system is adjusted to function at full capacity. Controlled drainage is used to treat agricultural runoff.

Effect on water pollution
Controlled drainage is used to reduce the load of nutrients to water systems and to even out and reduce acidic runoff peaks. By doing this, eutrophication and disturbances caused by acidic runoff in the water ecosystem and in fish fauna can be reduced.

According to some calculations, which are based on soil composition and simulated results, the total load of nitrogen from fields could be reduced with controlled drainage by 40% in comparison with traditionally drained fields (Vakkilainen & Paasonen-Kivekäs 1992).

Points to consider in planning
A controlled drainage system can be constructed in fields with sandy or fine sand soils. It is well suited for fields with special crops and acidic sulphate soils. In clayey and peat soils and in fields with a slope of over 2%, controlled drainage is not useful. The soil type of about 40 per cent of Finnish fields is such that controlled drainage could be used in them (Vakkilainen & Paasonen-Kivekäs 1992).

9.2.3
Green fallowing

Description of the method
The purpose of fallowing is on the one hand to increase the fertility of the land and on the other hand to decrease production. In traditional open fallowing the land is without a vegetation cover and it is tilled during the growing season to control weeds. When considering the goals of water protection, the best way to fallow is to use green fallowing. A green fallow is a field sown with plants to reduce erosion and the leaching of nutrients from the field. Different plants are chosen, depending on whether the goal is to protect the soil surface from erosion or to increase fertility.

Effect on water pollution
A study by Turtola (1992) showed that using rye-grass fallows was the best fallowing method for water protection. The leaching of nitrogen from an open fallow in clayey and fine sand soils was 4.5 times as great as from a fallow growing rye-grass. The amount of nitrogen leaching from open fallows in silty and peaty soils was almost three times as that of nitrogen leaching from rye-grass fallows. On peatlands, the leaching of phosphorus was twice as much as phosphorus leaching from a fallow growing meadow fescue and timothy grass. Also in clayey soils, fallows with timothy and rye-grass reduced the amount of phosphorus leaching.

9.2.4
Reducing the use of pesticides

Loading deriving from chemical pesticides can be reduced by using pesticides more carefully and according to instructions. Whenever possible, one should use biological and mechanical methods in pest and weed control.

9.2.5
Subsoil drainage

A significant percentage of nutrient loading on water systems is due to inadequate drainage. Poor drainage leads to increased surface runoff, which again leads to increased erosion and leaching of nutrients. Subsoil drainage decreases surface runoff, and the leaching of suspended solids and dissolved phosphorus is less than from fields with field ditches. Subsoil drains are perforated pipes placed under the soil surface. Subsoil drainage increases the area of arable land and facilitates moving with heavy machinery, which causes the earth material to become tightly packed. At present time more than half of Finnish fields have subsoil drainage.

Subsoil drainage reduces the loads of suspended solids and phosphorus, but increases the load of nitrate-nitrogen (Uusi-Kämppä 1989).

9.2.6
Lime filter drainage

Description of the method
Lime filter drainage includes a drain where calcium oxide is mixed in the excavated earth material. Because of the calcium oxide, the drain's ability to permeate water increases and runoff is filtered through the system so that even phosphorus transported in the water is absorbed into the drain. Lime filter drainage also reduces the acidity of sulphate soils.

Effectiveness of the method
In a study by Tikkanen (1998), the mean loss of phosphorus was 46%. According to the study, the method also effectively reduces the levels of acidic compounds and heavy metals leached from sulphate soils. In the Life-Lestijoki project, the loss of dissolved phosphorus was as high as 80%. In acidic sulphate soils, the ability of lime filter drainage to absorb phosphorus seemed to be reduced to nothing after a few years.

9.2.7

Buffer zones and strips

Description of the method

A buffer zone is a grassed or an uncultivated, vegetation-covered zone (or strip) used to separate fields and constructed areas from bodies of water. The permanent vegetation on the zone protects banks and littoral zones from erosion and from the leaching of nutrients, microbes and pesticides to the water. In addition, buffer zones also bring life to cultural landscapes and increase biological diversity in the area. From the viewpoint of water protection, buffer zones are particularly useful on fields that slope steeply towards water bodies or main ditches.

Effectiveness

According to a Finnish study, buffer zones of 10 metres have proved to be efficient in reducing the leaching of suspended solids, dissolved phosphorus and total nitrogen. During the four years of research, suspended-solid loads were reduced by 50–60%, leaching of nitrogen by 50% and leaching of phosphorus by 30%. Buffer zones also functioned well in exceptionally rainy and wet conditions, in which suspended-solid loads were reduced by as much as 80–90% (Uusi-Kämppä & Yläranta 1996).

Simulated tests employing the CREAMS model have shown that a buffer strip of 1 to 3 metres can already absorb half the sediment load deriving from mineral soils. On clayey and silty soils a buffer zone of 5 to 10 metres is needed to remove the same amount of sediment (Rekolainen 1992).

The efficiency of buffer zones in removing suspended solids and nutrients is affected by the width of the zone, gradient of the drained field, soil type and particularly by the variety and density of zone vegetation. If the zone is dominated by weeds, the absorbing capacity of the zone is poor. An efficient zone can be established by sowing it with a mixture of grass seeds, which grow into perennial, densely rooted and multi-layered plants. Good species are, for example, timothy grass, smooth meadow grass, foxtail, orchard grass, fescue grasses and common bent. Trees and bushes can also be planted on the zone. Buffer zones have to be maintained by mowing at least once a year. The removed vegetation has to be transported from the zone so that decomposing plants do not release more nutrients to the soil or to the body of water (Hänninen 1997).

Figure 9.1. Buffer zone of agriculture (Tiina Schultz).

9.2.8
Sedimentation basins

Description of the method

A sedimentation basin is a basin made in a ditch or a stream by digging or by damming. It is used to filter sediment (suspended solids) and nutrients from agricultural runoff. The functioning of a sedimentation basin is based on the deposition of soil particles on the bottom of the basin as the velocity and turbulence of the flow decrease. Apart from reducing loading on water systems, sedimentation basins enliven the landscape and promote the diversity of nature. In addition, they are good reservoirs for irrigation water.

The effect of sedimentation basins on the quality of agricultural runoff is studied by Agrifood Research Finland in a project on the regulation of water management to reduce phosphorus loading of water systems.

Effectiveness

In a study by Häikiö et al. (1998), sedimentation basins were found to remove mainly coarse-grained sediment from the runoff deriving from fields. At best, the loss of sediment was 60%, but more often the loss was significantly less. The loss of total phosphorus was recorded to be 6% and the loss of total nitrogen 3%.

In a study made in Köyliö in 1992–1995, a sedimentation basin removed 65% of the sediment and 35% of the total phosphorus load. Annual variations in the loss of phosphorus were considerable, ranging from -7% to 68%. Sediment losses ranged between 49% and 69%. The basin had no significant effect on the absorption of total nitrogen (Hirvonen et al. 1996).

In another study made in 1994, a wetland area was constructed in a ditch that runs to the Lake Rehtijärvi (in Jokioinen). This wetland area included a sedimentation basin and a wetland area. The losses in 1995 ranged from -22% to 26% for sediment, from

-93% to 52% for total phosphorus, and from 0% to 92% for total nitrogen (Puumala 1996).

The effects of three sedimentation basins have been studied in the Helsinki area in 1993–1994. One pond was found to retain small quantities of sediment and nutrients, one caused a slight increase in loading and one seemed to have no significant effect on loading. This study only examined the concentrations in the water flowing in and out of the basin. Because the discharge was not studied, the results are highly unreliable (Taponen 1995).

If sedimentation basins are to be used in the reduction of nitrogen concentrations, the basins have to be made considerably larger so that they will become more like wetland areas, where nitrogen is released into the atmosphere through denitrification.

9.2.9 Wetland areas

Description of the method
A wetland area is a section of a water system (ditch, stream, river etc.) or a littoral that is reserved or dammed to reduce the flow of harmful substances to the system. A wetland area is covered by water during high flows and remains moist even at other times.

Wetland areas are used to reduce concentrations of suspended solids and nutrients. The reductions are due to mechanical, chemical and biological processes. Suspended solids are removed from the water by depositing (the same way as in a sedimentation basin). The removal of phosphorus and nitrogen requires diverse operations and conditions in the area. Denitrification, which requires anaerobic conditions, is the main process in reducing nitrogen concentrations. Phosphorus leaves through a process of sedimentation, bound by suspended solids, and soluble phosphorus leaves by being absorbed by plants and the ground in aerobic conditions.

Effectiveness
In a study made in 1995, the use of a wetland area reduced suspended-solid loads by 7–33%, phosphorus loads by 25–48% and nitrogen loads by 20–90% in water that had first been treated in a sedimentation basin (Puumala 1996).

International research has produced varying results on the nutrient absorbing capacity of wetland areas. The absorption depends, among other things, on the size of the area, the vegetation in it and the incoming flow and loading. An anthology compiled by Leonardson (1994) shows that by controlling the quantity and quality of incoming water, phosphorus concentrations can be reduced by as much as 90–100% and nitrogen concentrations by as much as 76–90%. Meadows constantly covered with water absorb phosphorus and nitrogen efficiently. Reed fields are also efficient in absorbing nitrogen.

Figure 9.2. Wetland area of agriculture (Riina Koivuranta).

9.3

Water pollution control methods in forestry

Loading caused by forestry on waters

Forestry activities, such as drainage, felling, soil cultivation and fertilisation, cause suspended-solid and nutrient loading of water systems. Numerous studies have found that drainage and soil cultivation increase runoff and the leaching of suspended solids, nutrients and iron. Clear cuttings increase the leaching of nutrients and iron. Fertilisation increases the leaching of phosphorus from peatlands and the leaching of nitrogen from mineral soils.

Water pollution control methods used in forestry

- drainage
- digging breaks and dredging breaks
- temporary weirs
- submerged weirs
- lighter soil cultivation
- reducing fertilisation
- avoiding the use of pesticides
- sludge sumps and sludge pockets
- buffer zones
- sedimentation basins
- overland flow areas (wetland areas)

9.3.1

Drainage

Description of the method

The goal of forest drainage is to remove excess water from the soil surface because excess water hinders the growth of trees. Draining always leads to some degree of erosion. The extent of erosion depends on soil type, the longitudinal gradient (sloping) of the ditches and the quantity and flow velocity of the water flowing in the ditches. The effects of ditch maintenance on water systems are quite similar to those of newly drained areas. The leaching of suspended solids caused by ditch maintenance can, however, be greater than that caused by drainage if the bed of the cleaned ditch extends to easily eroded mineral soil layers (Metsätalouden ympäristöopas 1997, Joensuu 1999).

Points to consider in planning

The digging of ditches parallel to the direction of the main inclination should be avoided in order to keep flow velocity as low as possible and the amount of erosion as small as possible. The Forestry Development Centre Tapio recommends the following maximum ditch gradients for different soil types (unit: m 100 m^{-1}): clay 2, silt 0.7, fine sand 0.4, coarse-grained sand 0.9, decomposed peat 1.5. If the drained area is larger, the gradients have to be smaller.

Conveying runoff from several field ditches straight to the water body should be avoided. Instead, the runoff should be conveyed to water bodies through main drains. Before allow ing the drained water to enter water bodies, the water should be treated with the water clarification method that is best suited for the target area (sedimentation basin + overland flow area).

By timing the draining activities right, suspended-solid and nutrient loading caused by drainage can be reduced. Ditch-digging has to be done during the driest possible period. Digging should be avoided during periods when frost melts. When there is substantial runoff, the upper ditches should be excavated first, then the lower ditches, and the main ditches leading to water bodies last.

9.3.2

Digging and dredging breaks

Digging breaks

Digging breaks are fragments of 10 to 30 metres, which are left intact (i.e., not excavated) in field ditches. After a break in the ditch, discharge runs as surface runoff, the same way as in buffer zones. After this, the runoff is conveyed back to the ditches through a trap (forked) drain. Breaks can be used in ditches that have an adequate gradient (sloping). Breaks prevent flow velocities from becoming too high and function as barriers against suspended-solid loading.

If a permanent digging break cannot be taken into use for technical reasons, a temporary weir (barrier) can be used to induce surface flow. Temporary weirs are best suited for areas with fine sorted soil and with a relatively strong water flow (Joensuu & Kokkonen 1992).

Dredging breaks

Dredging breaks are gaps in ditches, which have not been dredged during ditch maintenance. Dredging breaks decrease flow velocity and retain loads of suspended solids and nutrients.

9.3.3
Submerged weirs

To slow down the flow velocity of water and to prevent the erosion of ditches, submerged weirs can be constructed. Submerged weirs are constructed on ditch beds out of wood, stone or other materials. In sloping, straight ditches, several consecutive weirs can be constructed if necessary.

Submerged weirs mainly diminish the loading of suspended solids and nutrients (transported by the suspended solids) on water systems (Joensuu 1999).

Figure 9.3. Submerged weir of forestry (Samuli Joensuu).

9.3.4
Lighter soil cultivation

Description of the method
The soil surface has to be tilled to ensure forest regeneration. Mechanical tilling breaks the surface layer of soil, which increases runoff and erosion. Heavy tilling increases the leaching of suspended solids (sediment) in particular, but also the loads of phosphorus and nitrogen increase. According to the Environmental Programme for Forestry, ploughing of mineral soils was to be discontinued by the end of 1996. In areas owned by the National Board of Forestry, forest ploughing was discontinued in 1994. Soil improvement methods used in these areas include controlled burning, patch scarifying, harrowing, scarification/mounding and furrowing/mounding.

Points to consider in planning
Controlled burning is best suited for moraine soils, which have coarser soil texture than fine sand soils. Patch scarifying (scarification) can be used on permeable, barren sorted and coarse moraine soils that have a thin raw-humus layer. Harrowing can be used for medium coarse, permeable moraine soils that have a thin raw-humus layer. Scarification/mounding is suitable for medium coarse and fine-sorted frost-susceptible soils that can have a relatively thick raw-humus layer. Furrowing/mounding is used in miry areas and in areas where waters cause problems.

9.3.5

Reducing fertilization

Fertilisers are used in forests to maintain the condition of the forest and to increase productivity. The main nutrients used in fertilisers are nitrogen, phosphorus, potassium and boron. Ash can also be used as a fertiliser. The fertilisation of peatlands has been found to increase the leaching of phosphorus if the fertiliser contains soluble phosphorus. Using phosphoric fertilisers on mineral soils does not usually increase phosphorus loading of water bodies because phosphorus is bound by the iron and aluminium compounds in the soil. Instead, the leaching of nitrogen from mineral soils may increase temporarily as a result of fertilisation. The nitrogen from fertilisers is transported mainly as nitrate to water bodies (Joensuu 1999).

The Forestry Development Centre Tapio has recommended that an unfertilised strip of 10 to 15 metres be left around streams and a strip of 50 metres around other bodies of water. The purpose of this is to prevent the leaching of nutrients into the water. Peatlands that are in important groundwater areas are not fertilised at all. It is recommended that fertilisers be used only when the ground is unfrozen, which prevents the leaching of nutrients with melt waters (Joensuu 1999).

9.3.6

Avoiding the use of pesticides

Chemical pesticides are used to remove grass and hay vegetation, which hamper the early development of saplings. The transport of pesticides to water systems has to be prevented, as most of them are hazardous (at least to a small degree) for fish and other aquatic fauna.

Pesticides should only be used at selected sites and even then only in prescribed amounts. In groundwater areas and near springs and water intake structures pesticides should not be used at all. A buffer zone (the width of which has been recommended by the manufacturer of the fertiliser) has to be left between the application area and the water body. The equipment used in the application of pesticides may not be cleaned directly in the water body (Joensuu & Kokkonen 1992).

9.3.7

Sludge sumps and sludge pockets

Description of the method
A sludge sump is a hollow of 1–5 m^3 in a field ditch. The bottom of the hollow is usually 1–1.5 metres below the bottom of the ditch. A sludge sump can also be quite a long hollow extending into the side of the ditch, in which case it is called a sludge pocket. The purpose of these sumps is to stop the transport of coarse sediment in field ditches during ditching and the subsequent few years of high sediment leaching. Several successive holes can be excavated in the same ditch.

Points to consider in planning
The following points should be considered when planning and digging sludge sumps and sludge pockets (Joensuu & Kokkonen 1992):

- sumps should be constructed in places where flow velocity naturally slows down
- if necessary, several hollows (sumps) can be placed in a single ditch; in long ditches, the distance between hollows should not be too long

- often a sludge sump is needed when runoff is conducted to a culvert, to an agricultural ditch or to farm land outside the drained area
- a ditch can also terminate at a sludge sump if runoff is conducted as surface runoff or through a buffer zone to a water system below the drained area.

Figure 9.4. Sludge slump of forestry (Samuli Joensuu).

9.3.8
Buffer zones

Description of the method
A buffer zone is an undrained area between a water body (or another specific site) and a forestry area. Drained water is conducted to the water body through the buffer zone. The purpose of this is to decrease the sediment and nutrient loading of water systems. Loading is reduced as a result of physico-chemical and biological processes taking place in the buffer zones.

Effectiveness
In a study conducted in Nurmes, Finland, buffer zones were found to be efficient in retaining sediment and nutrient loads deriving from clear cuttings and tilling. According to the study, clear cutting and tilling in an area with a buffer zone caused no significant changes in the amount of sediment, total phosphorus and total nitrogen leached by runoff. In an area without a buffer zone, the leaching of total phosphorus was four times and the leaching of nitrogen twice as high as before cuttings. Tilling after the cuttings affected the leaching of sediment most: it was 200 times the amount of leaching from a natural area. Nitrogen loading after tilling was three and phosphorus loading four times the amount of loading from natural areas (Kenttämies & Saukkonen 1996, Huttunen et al. 1990).

Figure 9.5. Buffer zone of forestry (Samuli Joensuu).

9.3.9

Sedimentation basins

Description of the method

Runoff from forestry areas is conducted to sedimentation basins, which are excavated in connection with outfalls. The purpose of sedimentation basins is to remove sediment (suspended solids) and nutrients from the runoff. The functioning of sedimentation basins is based on the deposition of sediment as the flow velocity decreases.

Effectiveness

Well-functioning sedimentation basins can remove 30–50% of the sediment load. On fine mineral soils it is recommendable to use additional water pollution control methods, such as overland flow areas and buffer zones (Joensuu 1999).

The effect of sedimentation basins on sediment leaching has been studied in a project called METVE, which took place in 1990–1994 (Kenttämies & Saukkonen 1996). The study focused on 40 target areas, each of them comprising an activity area and a reference area. The results show that sedimentation basins function relatively well on coarse-textured and medium coarse-textured soils, but the effect on finer soils was insignificant. Nearly half of the studied sedimentation basins reduced the sediment load by 20%. A little less than a fifth of the basins reduced sediments by more than 50%. About a quarter of the basins were only able to reduce the load by less than 5%. In two basins the amount of sediment discharging from the basin exceeded the amount of sediment transported to the basin (Ahti et al. 1995).

Points to consider in planning

Sedimentation basins are placed in the sills of outfalls where the flow velocity naturally slows down. Basins have to be placed sufficiently far away from the mouth of the outfall so that they are not submerged during floods. The edges of the basins have to be made to slope gently so that if an animal falls into the basin, it can make its way out. The outfall of the basin has to be made lower than usually, or it is not excavated at all, which leaves room for the depositing sludge.

Figure 9.6. Sedimentation basin of forestry (Samuli Joensuu).

9.3.10
Overland flow areas and wetland areas

Description of the method
An overland flow area is an area covered by vegetation, into which runoff from forestry is conducted. The runoff on overland flow areas is cleaned as a result of physical, chemical and biological processes. The use of overland flow areas (or other infiltration areas) is the primary water pollution control method used to reduce loading deriving from forestry (Hänninen et al. 1995).

Effectiveness
The effectiveness of overland flow areas has been studied in the North Karelia Regional Environment Centre. The areas were constructed by leaving unexcavated ditch breaks of about 15 metres in the outfalls of forestry areas. These outfalls were then blocked with peat mats and staked with a line of buttresses and stones. Willow cuttings were planted on the ditch breaks. Altogether 30 overland flow areas were studied in the summer of 1998 to investigate the effect they had on loading. Sediment loads were reduced by 22–37%, total phosphorus by 22–37% and total nitrogen by 22–31% (Tossavainen et al. 1999a & b).

Points to consider in planning
An overland flow area can, for instance, be a part of a ditch maintenance area or a natural mire. The surface layer of an overland flow area should consist of peat. The area should be so large that the water flow slows down or stops completely. The area should be 1–2% of the drainage basin area. A feed ditch is often excavated above the area so that the distribution of water in the area would be as even as possible. (Joensuu 1999).

Figure 9.7. Owerland flow area of forestry (Samuli Joensuu).

Figure 9.8. Wetland area of forestry (Samuli Joensuu).

9.4
Water pollution control methods in peat mining

Loading caused by peat mining on waters
Sediment (suspended solids), nutrients, organic matter and iron are leached into water systems from peat production areas. The phosphorus and nitrogen load caused by peat mining is only about 1% of the total load to water systems, but locally it can

have a significant effect on water quality. The phosphorus load caused by peat mining areas on water systems was 50 tons and the nitrogen load 1100 tons in 1994.

Objectives of water pollution control in peat mining
According to a decision in principle from the Finnish government (19.3.1998), the phosphorus and nitrogen loading of waters caused by peat mining will be reduced by at least 30% from the 1993 level by the year 2005 .

Listed below are some widely used water pollution control methods in peat mining :

- field ditch structures
- sedimentation basins
- overland flow areas
- chemical water treatment.

In addition to the methods mentioned above, several new methods are being developed:

- peak runoff control
- soil filtering
- evaporation basins
- pipe drainage using water-carrying boards
- rock wool filtration
- artificial flood plains
- mole drainage
- peat filtering.

Figure 9.9. Sedimentation basin of peat mining (Jari Vilen).

9.5

Wastewater treatment in rural areas

According to Finland´s Environmental Protection Act, wastewater in areas not connected to any centralized sewerage system must be treated so that it does not pollute the environment and there is no risk of pollution.

New wastewater treatment requirements

The Decree stipulates that at least 90% of the organic material (BOD_7) should be removed from wastewater, as well as >85% of total phosphorus and >40% of total nitrogen with regard to the person equivalent load defined in the Decree. Municipalities may also take local conditions into account and enforce slightly higher or lower standards in municipal environmental protection regulations where this is justifiable.

Treatment facilities to meet new requirements by 2014

The requirements in the Decree apply immediately to all new buildings, while wastewater treatment systems of buildings completed before 1.1.2004 must in most cases be upgraded to fulfill the new standards by 1.1.2014.

If only very small amounts of wastewater are generated, 'grey wastewater' from kitchens and bathrooms may be simply released into the ground untreated. This wastewater may not contain toilet waste, or represent any other type of pollution risk.

9.6

Possibilities of the restoration and the water protection

Effect of external and internal loading

External loading has mainly caused the eutrophication of many lakes. Eutrophication of lakes reduces the retention mechanism of phosphorus. When much organic matter is produced, the sediment of lake does not retain the phosphorus as effectively as in more oligotrophic lakes. Phosphorus is released when organic matter is decomposed but phosphates are partly settled as iron, aluminium or calcium phosphates. Iron can bind phosphorus only as Fe^{3+} compounds. In sediments, due to decomposition of organic matter, iron is reduced into Fe^{2+} and phosphates are dissolved (Bilaletdin et al. 2004).

Raising water levels

In many cases the state of the lake would be better if the water levels were higher. Mainly this means lakes in the catchment area, not as big lakes as Lake Onega. The volume of the lake would be large which would make retention of phosphorus more efficient. Also if macrophytes on the shore are a problem, their growth could be reduced by raising water level. In practice, raising of water level may be impossible if there are houses, other constructions and cultivated fields on the shoreline. In many cases a more suitable method is to raise only the lowest water levels. The most serious water quality problems often occur when the water levels are the lowest.

Oxygenation

Even if external loading could be reduced the recovery of the lake might take a long time because of internal loading. Internal loading can be reduced by means of several restoration methods. One of the most widely applied method is oxygenation of the lake. It is mainly based on the idea that iron is oxidized into Fe^{3+} form which binds phosphorus in the sediment. The deepest parts of the lake may occasionally suffer from oxygen depletion. In the deeper layers of the sediment, anoxia is natural but if the sediment surface is aerobic, phosphorus cannot return into the water, presuming that there is sufficiently iron present.

Biomanipulation

Biomanipulation is today a widely applied means of lake restoration. It is based on the idea that phytoplankton production can be reduced by changing the structure of the ecosystem. It has e.g. been found that at a certain level there are two possible structures of the ecosystem, one possibility with high phytoplankton biomass, low zooplankton biomass, large population of planktivorous fish and small population of predatory fish, and the other possibility vice versa.

The most common method of biomanipulation is effective fishing of planktivorous fish. Stockings of predatory fish are also used. Most of the biomanipulation case studies have been reported on the basis of empirical data but there are also predictive models describing the phenomenon theoretically (e.g. Sagehashi et al. 2000). This kind of models require a comprehensive data base of the case study lake.

Dredging

One method of reducing internal loading is to remove the soft sediment. It would no doubt be effective but it would have harmful side effects. It would change the ecosystem. Benthic animals would be reduced along with the sediment. Fish stocks would suffer or even totally collapse and it would take a long time before a sound ecosystem would develop. Dredging would also make the water temporarily turbid.

One major problem is also the placement of the sediment. If the sediment is located too close to the shore the nutrients will return into the lake. The soft sediment should be totally removed. Otherwise the method is not necessarily effective. The method is very expensive and technically difficult. Before trying other options, it cannot be recommended.

Figure 9.10. Restoration dredging (Tiina Schultz).

10 Conclusions

While Lake Onega preserves a good status of water as a whole, the problems with pollution and eutrophication exist in Petrozavodsk and Kondopoga Bays where anthropogenic loading is more pronounced.

The Petrozavodsk Bay has better exchange with the open central part of the lake, but in winter time and during the thermal bar existence (late spring – early summer) water quality can deteriorate, when Shuya flood waters are locked in the bay.

The Kondopoga Bay is more isolated from the central part of the lake. Here the anthropogenic impact is most severe, the pollution is heaviest at the head of the bay throughout the year, where the Kondopoga PPM withdraws wastewaters for nearly 80 years (40 years without treatment), throughout the year.

As a consequence of human impact on Lake Onega is a rise in its nutrient status. The Petrozavodsk industrial centre is the main eutrophying agent for the central part of the lake, whereas Kondopoga pulp-and-paper mill wastewaters are more localized within the bay. Nevertheless, a certain decrease of bottom dissolved oxygen concentrations is found to exist in lake proper in the vicinity of the bay.

The excessive phosphorus loading with Petrozavodsk wastewaters should be reduced considerably to prevent further eutrophication of Lake Onega. The existing treatment removes about 55-60% of total phosphorus from Petrozavodsk wastewaters. A modern technology permits to increase this figure up to 95%.

To improve environmental conditions in Kondopoga Bay the effectiveness of wastewater treatment process at Kondopoga PPM has to be enhanced and phosphorus loading has to be reduced.

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Tekijä(t)	Victor Podsechin, Heikki Kaipainen, Nikolai Filatov, Ämer Bilaletdin, Tom Frisk, Arto Paananen, Arkady Terzhevik, Heidi Vuoristo		
Julkaisun nimi	**Development of water protection of Lake Onega** (Äänisjärven vesiensuojelun kehittäminen)		
Julkaisusarjan nimi ja numero	Suomen ympäristö 36/2009		
Julkaisun teema	Ympäristönsuojelu		
Julkaisun osat/ muut saman projektin tuottamat julkaisut			
Tiivistelmä	Äänisjärvi on Laatokan jälkeen Euroopan toiseksi suurin järvi. Se sijaitsee Karjalan tasavallassa sekä Leningradin ja Vologdan alueilla Venäjän federaatiossa. Järven pinta-ala on 9 800 km^2, sen maksimisyvyys on 127 m ja keskisyvyys noin 30 m. Tärkeimmät kaupungit järven rannalla ovat Petroskoi ja Kontupohja. Järvi laskee Itämereen Syvärin, Laatokan ja Nevan kautta. Venäjä ei ole liittymässä Euroopan unioniin (EU) lähitulevaisuudessa. Kuitenkin myös Venäjällä on pyrkimys soveltaa monien EU-direktiivien keskeisiä periaatteita. Vesipolitiikan puitedirektiivi (vpd) on hyödyllinen direktiivi linjaamaan vesienhoidon järjestämistä. Projektin tarkoituksena oli selvittää Äänisjärven nykyinen tila, arvioida järveen kohdistuvia paineita ja riskejä sekä laatia vesiensuojelun yleissuunnitelma turvaamaan järven hyvä ekologinen ja kemiallinen tila vpd:ssä esitetyllä tavalla. Yksi projektin tavoitteista oli siirtää vpd:tä koskevaa suomalaista asiantuntemusta ja suomalaisten tutkimusten tuloksia Äänisjärven alueelle. Tässä projektissa sovellettiin useita erilaisia tasapainotilaan perustuvia ja dynaamisia valuma-aluemalleja ja järven vedenlaatumalleja, joilla arvioitiin eri kuormitusskenaarioiden vaikutuksia. Vaikka Äänisjärvi kokonaisuutena näyttää pysyvän hyvässä tilassa, veden pilaantumis- ja rehevöitymisongelmia on Petroskoin ja Kontupohjan lahdissa, missä ihmisen aiheuttama kuormitus on selkeimmin havaittavissa. Petroskoin jätevesien liiallista fosforikuormitusta tulisi huomattavasti vähentää Äänisjärven rehevöitymisen estämiseksi. Nykyinen käsittely poistaa Petroskoin jätevesien kokonaisfosforista noin 55 – 60 %, kun nykytekniikalla on mahdollista päästä 95 %:iin. Kontupohjan lahdessa ihmistoiminnan vaikutus on selvin, ja vesien pilaantuminen on läpi vuoden voimakkainta lahden pohjukassa, mihin Kontupohjan sellu- ja paperitehdas on laskenut jätevetensä jo lähes 80 vuotta (, mistä ajasta 40 vuotta ilman käsittelyä). Kontupohjan lahden ympäristön tilan parantamiseksi tehtaan jätevesien käsittelyprosessia tulisi parantaa ja tehostaa ja erityisesti fosforikuormitusta tulisi vähentää.		
Asiasanat	Äänisjärvi, vesipolitiikan puitedirektiivi, vesiensuojelu, rehevöityminen, fosfori		
Rahoittaja/ toimeksiantaja			

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Author(s)	Victor Podsechin, Heikki Kaipainen, Nikolai Filatov, Ämer Bilaletdin, Tom Frisk, Arto Paananen, Arkady Terzhevik, Heidi Vuoristo		
Title of publication	**Development of water protection of Lake Onega**		
Publication series and number	The Finnish Environment 36/2009		
Theme of publication	Environmental protection		
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Abstract	Lake Onega is the second largest lake in Europe after Lake Ladoga. The lake is located in the Karelian Republic, in the Leningradskaya and Vologodskaya regions of the Russian Federation. The area of the lake is 9800 km^2, its max depth is 127 m and the average depth about 30 m. The main cities situated on the shore of the lake are Petrozavodsk and Kondopoga. The lake is connected to the Baltic Sea via the River Svir, Lake Ladoga and the Neva River. Russia is not joining the European Union (EU) in the near future. However, there is tendency to adopt the central principles of many EU directives also in Russia. Water Framework Directive (WFD) is a useful directive giving the main guidelines about how to organize water management. The aim of the project was to make an investigation of the status of Lake Onega, to assess pressures and risks into the lake and make a general plan for water protection to guarantee a good chemical and ecological status of the lake, as expressed on the WFD. One purpose of this project was to transfer Finnish knowledge and results of Finnish investigations concerning the WFD to the area of Lake Onega. In this study, many different steady-state and dynamic catchment and water quality models were used in assessing the effects of different loading scenarios. While Lake Onega preserves a good status of water as a whole, the problems with pollution and eutrophication exist in Petrozavodsk and Kondopoga Bays where anthropogenic loading is more pronounced. The excessive phosphorus loading with Petrozavodsk wastewaters should be reduced considerably to prevent further eutrophication of Lake Onega. The existing treatment removes about 55-60% of total phosphorus from Petrozavodsk wastewaters. Modern technology permits to increase this figure up to 95%. In Kondopoga Bay anthropogenic impact is most severe, the pollution is heaviest at the head of the bay throughout the year, where Kondopoga PPM withdraws wastewaters for nearly 80 years (40 years without treatment). To improve environmental conditions in Kondopoga Bay the effectiveness of wastewater treatment process at Kondopoga PPM has to be enhanced and phosphorus loading has to be reduced.		
Keywords	Lake Onega, Water Framework Directive, water protection, eutrophication, phosphorus		
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