stowa

RAM, versie 1.0

NEERSLAG AFVOERMODULE
(Handleiding)

96–03

TEN GELEIDE

Inzicht in het neerslag-afvoerproces is onontbeerlijk in het dagelijks waterbeheer. Hierbij gaat het zowel om het afvoerverloop als om de uit- en afspoeling van nutriënten naar oppervlaktewater. Eén van de beperkingen bij het gebruik van oppervlaktewatermodellen, zoals DUFLOW, HYDRA of Sobek, is het ontbreken van een goede beschrijving van het neerslag-afvoerproces.

Het project de ontwikkeling van de neerslag afvoermodule RAM is gestart met een enquête onder ruim dertig waterbeheerders om de huidige toepassingen en de knelpunten in kaart te brengen. Hieruit bleek dat de module zoveel mogelijk diende aan te sluiten op bestaande en veel gebruikte neerslag-afvoermodellen. Bij de bouw van RAM is dus nadrukkelijk gestreefd naar een integratie van bestaande modellen.

Bij de ontwikkeling van RAM is gesteld dat de module geschikt moet zijn voor operationeel gebruik. Hiervoor is gestreefd naar een zo eenvoudig mogelijk concept met een hoge mate van toegankelijkheid. De module diende tevens een directe koppeling tot stand te brengen tussen een neerslag-afvoermodel en oppervlaktewatermodellen door aan te sluiten op de STOWA/Unie stekkerdoos Water. RAM kan derhalve zowel stand-alone als gekoppeld aan een oppervlakte-watermodel gebruikt worden.

Het raamwerk van RAM onderscheidt deelprocessen voor open water-, verhard- en onverhard oppervlak. Per deelproces wordt, voor zover relevant, gekeken naar infiltratie van het bodemvocht, percolatie naar het grondwater en grondwaterafvoer naar het afwateringsstelsel. Uit- en afspoeling wordt beschreven door aan de verschillende deelstromen (stikstof, fosfor en ammonium) concentraties toe te kennen die worden beïnvloed door additionele bronnen en reactieprocessen.

De gebruikershandleiding zal in het engels worden uitgebracht, voor een vertaling van de begrippen wordt verwezen naar appendix III en/of de verklarende hydrologische woordenlijst van CHO-TNO. Het technisch ontwerp en de filosofie achter RAM zal in STOWA-rapport 96-14 uitgebreid (in het Nederlands) worden beschreven.

De werkzaamheden zijn uitgevoerd door een projectteam, met als projectleiders voor de software ontwikkeling en coördinatie van het tesprogramma ir. J.J. Noort van EDS en voor de definitiefase, enquête onder de waterbeheerders en het technisch ontwerp ir. A.P. Salveda van Witteveen+Bos. Projectmedewerkers bij Witteveen+Bos waren ir. R.M. van den Boomen, drs. J.L.P.M. van der Pluim, mevr. ir. P. Goessen en bij EDS ir. P. van der Berg en mevr. drs. J. van Besouw.

Het project is begeleid door een begeleidingscommissie, waarvan de leden afkomstig zijn uit deel-nemers in de stichting en bestaande uit: ir. A. van Asperen (voorzitter), ir. R. Groen, ing. C.G.P. Groen in 't Woud, ing. A.P.A. Kuypers MSc., ir. H.J. Koskamp, ir. A. G. Kors en ir. L.R. Wentholt.

Dank is de STOWA verschuldigd aan de volgende externe experts: ir. R.H. Aalderink (LUW, vakgroep waterkwaliteitsbeheer en aquatische ecologie), dr. ir. N. Booij (TUD, Civiele Techniek), ing. G.J.E. Hartman (LBL), ir. J.M.P.M. Peerboom (DLO - SC) en ir. P.M.M. Warmerdam (LUW, vakgroep waterhuishouding).

Utrecht, april 1996   De directeur van de STOWA

drs. J.F. Noorthoorn van der Kruijff

Contents

1. Introduction

1.1 Purpose

Water authorities require a dynamic management of their extensive water systems and related infrastructure to provide water for industry, agriculture, domestic supply, reduction of damage due to excess of water, water quality control, etc. In hydraulic engineering a proper design and operation of river based structures and improvement works also requires consideration of the overall water system . The use of surface water models suiting a wide range of users and their applications has become a prerequisite for optimal design and management.

One of the restrictions of most of the surface water models is the absence of an accurate description of the precipitation runoff process. In order to improve the applicability of the surface water models, STOWA has initiated the development of a precipitation runoff module (RAM).
An adequate description of the precipitation runoff processes is necessary for the prediction of runoff peaks and the prediction of the water quality in the surface water.

RAM is suitable for operational use.

The current version of RAM uses DUFLOW based files to communicate with other programs. In future the communication with the surface water models will be made using the standard exchange format of STOWA (SUF-OW). At the start of this project the definition of SUF-OW was not completed.

Minimal Hardware and software requirements
IBM-PC 386
8 Mbyte
MS Windows 3.10

1.2 About this manual

In the Chapter Background (see page 2) the setup of the mathematical model is given. This chapter is divided in the sections: Theory, General Setup and Formula's. In the section Theory an explanation on the hydrological cycle, the nitrogen cycle and the Phosphor cycle is given. In the section General Setup a general description of the model is given, while in the section Formula's an extensive description of the governing equations is given.

If you are new to RAM please read the chapter on Getting Started (page 51). In this chapter a step by step instruction of the most important features of RAM is given. In the chapters Commands (page 61) and Dialogs (page 68) you will find a complete reference to the functions of RAM.

2. Background

2.1 Theoretical System Description

Insight into the various hydrologic processes is necessary for a correct description of the precipitation runoff processes. The same applies to giving a correct description of runoff and leaching, which requires insight into the mass balances.

Preceding the Formulas, the hydrologic cycle (section 2.1.1) and the nitrogen and phosphor balances (section 2.1.2) are explained in this chapter. It is not intended to give an exhaustive explanation (for this reason the literature is referred to). But, a short description that is sufficient as reference for this manual.

Precipitation runoff processes are generally described at a catchment area level. Within a catchment area, the relevant parameters may vary substantially (soil type, slope, land use, etc.). A detailed physical description of the occurring processes is, therefore, difficult to give. In the literature, the hydrologic cycle is generally described as a chain of processes (indicating the course of processes and quantifying the amounts by means of water balances). This also applies to mass balances. In this chapter, this point of view is the point of departure.

2.1.1 Hydrologic Cycle

The Hydrologic Cycle is a continuous process in which water circulates from the oceans through the atmosphere and the rivers back to the ocean. In figure 1 the hydrologic cycle is outlined in a schematic cross section. The various processes are reflected in a flow chart in figure 2.

Ocean water evaporates into the atmosphere. This water falls as precipitation partly on the land surface and partly on the sea surface. The precipitation that falls on the land surface, is stored temporarily on vegetation (interception), on objects, on the surface (depressions), in the soil (replenishment of soil moisture and ground water reservoir) and in open waters. The surplus precipitation, this is the precipitation that does not evaporate eventually, will end up running off as ground water or surface water eventually (Van Dam, 1991).

Before precipitation is discharged, it goes through various processes. Part of the precipitation will evaporate. The amount of precipitation that is drained during a time interval, cannot be put on a par with the difference between the precipitation and the evaporation, due to the buffer effect of the terrain, the subsoil and the drainage system. This buffer effect, which is the resultant of a number of reservoir effects of different natures and sizes, leads to time shifts between the amounts of precipitation, evaporation and discharge belonging together. The larger a time interval is taken and, therefore, the smaller the total reservoir effect is, the more the discharge will approach the difference between precipitation and evaporation. The total storage effect is, however, important to the determination of a

surplus. The storage effects are less important to the total drainage during a longer period of time, but are aimed at determining the items in the water balance (Warmerdam, 1994).
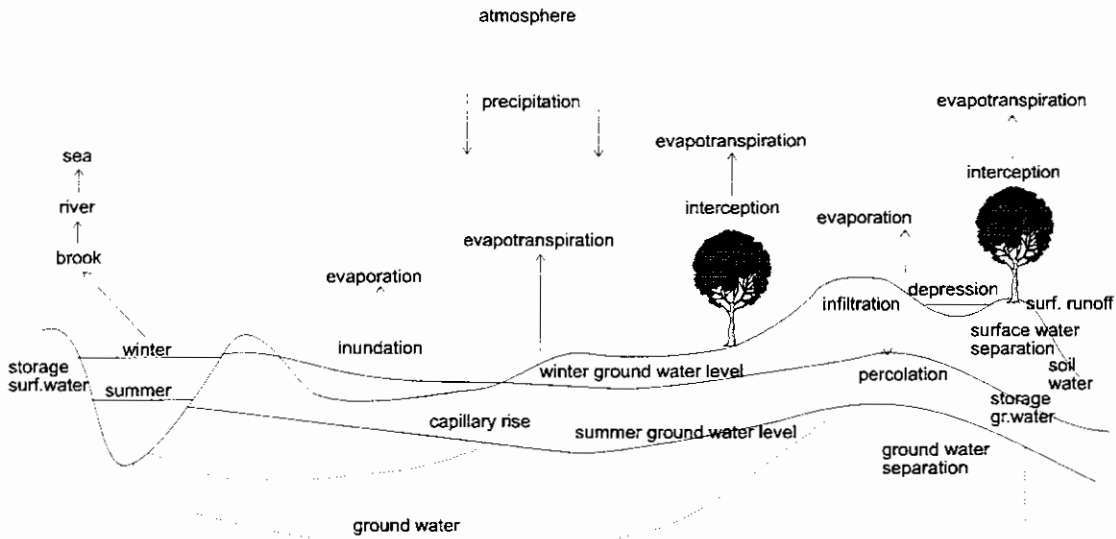
figure 1: Hydrologic cycle (Warmerdam, 1994)
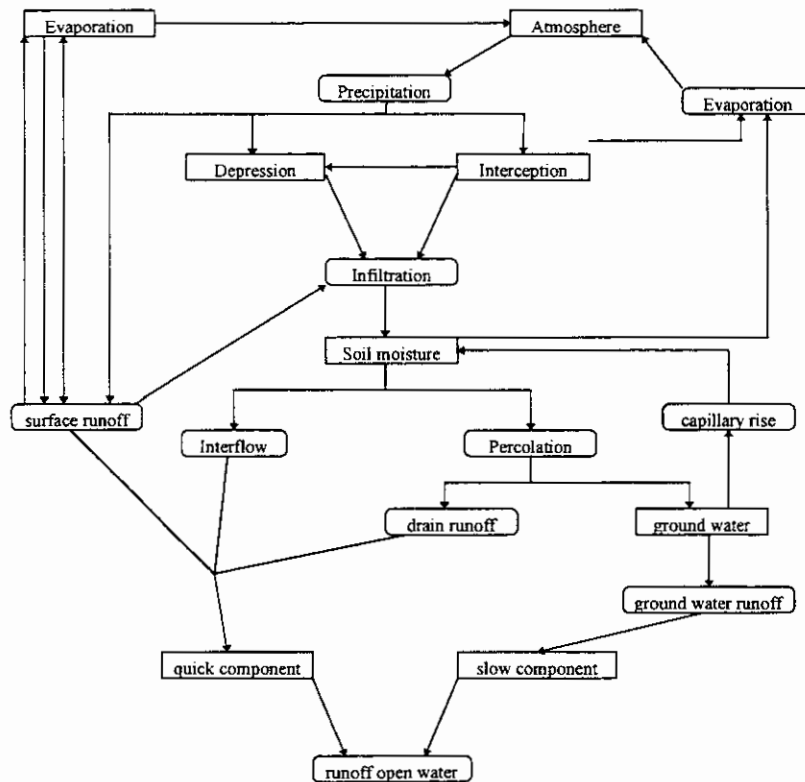
figure 2: Hydrologic cycle flow chart

In the flow chart, the ground water flows (the items seepage and downward seepage) have been left out, in order to keep the chart surveyable. Also the meltwater drainage (and storage in the form of snow) has been left out of consideration. This process is not included in the precipitation runoff module. Furthermore, artificial supply (inlet) or extraction of water have been left out of consideration.

The precipitation runoff processes are described in the following sections. In this description paved and unpaved surfaces are distinguished between.

2.1.1.1 Paved surface

Within paved surface a further distinction may be made in:
- Paved surface in a rural area;
- Urban area;
- Greenhouse area;

The precipitation on paved surface in a rural area is discharged immediately by means of the surface (ditches), or it is discharged by means of the ground water due to infiltration outside the paved area.

Precipitation in urban areas will partly fall on paved surface (roads, buildings) and partly on unpaved areas (parks, gardens). The precipitation on the paved surface (ground precipitation) will be drained through the sewer system. Part of this precipitation will temporarily be stored on the street surface. The precipitation on unpaved surface will be drained through the soil or the drainage system.

The way in which precipitation is discharged depends on the type of sewer system. In case of a combined sewer system, the precipitation is discharged in principle through sewage treatment plants. In case of extreme precipitation, part of the precipitation will be discharged into the surface water by means of overflow.

In case of a separated sewer system, the precipitation on paved surface will be discharged into open waters immediately. Part of the precipitation will be stored temporarily in the sewer system and in case of extreme precipitation on the paved surface. In case of an improved separated sewer system, the water is discharged to sewage treatment plants when little precipitation occurs (highly polluted water). In case of heavier precipitation, the water will be discharged directly into the surface water (this water is considerably less polluted).

The precipitation on greenhouses is discharged directly or through a water storage reservoir to surface water.

2.1.1.2 Unpaved surface

Within the discharge process of unpaved surface, three processes are distinguished (see figure 3):
1. Infiltration into the soil moisture (unsaturated zone)
2. Percolation into the ground water (saturated zone)
3. Ground water discharge into the drainage system

1. Infiltration into the soil moisture (unsaturated zone)

Precipitation on unpaved surfaces is caught by the vegetation (interception) and the soil. The amount of precipitation that is caught by the vegetation is difficult to determine, as is the amount of water that reaches the ground by flowing along the trunks of trees and through foliage. This interception causes slowing down (and also extra evaporation) of the runoff process, but has hardly any effect on the effective precipitation (Singh, 1989). In general, losses as a result of interception are small, except in woodlands.

precipitation

evapotranspiration

interception   evaporation   transpiration

surface runoff

interflow

infiltration

absorption by roots

percolation   capillary
rise

> ground water discharge

downward
seepage   seepage
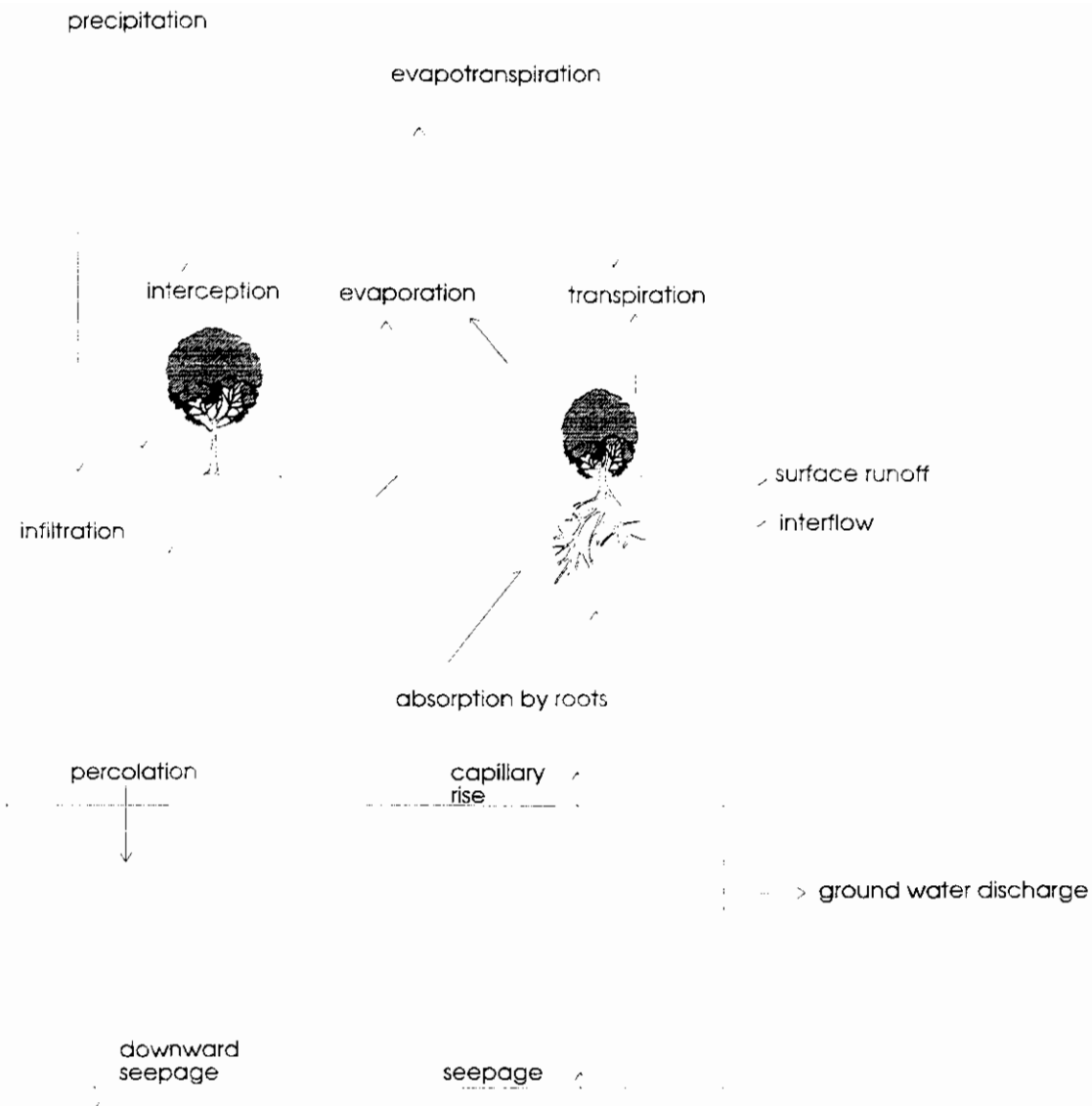
figure 3: Hydrologic processes unpaved surface

Precipitation that reaches the surface, will infiltrate and will be stored in the soil moisture zone. The amount of precipitation, which is stored in the soil, depends on the precipitation intensity and amount, as well as the infiltration capacity. The infiltration capacity describes the amount of water, which may infiltrate into the ground within a time unit. This depends on the nature and the state of the ground (water content, cultivation, presence of vegetation). If the precipitation intensity surpasses the infiltration capacity, the water stays behind on the surface level. A water film is formed on the surface, which fills the hollows (surface depressions). In case of prolonged precipitation, this precipitation will partly evaporate and partly flow off through trenches in the depressions (surface runoff). Surface runoff is characterized by short but heavy runoff/discharge peaks and represents a quick component of the runoff process.

The storage in surface depressions depends to a large extent on the roughness of the terrain. In The Netherlands, the infiltration capacity is often high and the precipitation intensity low, so that discharge of the precipitation over the surface level plays a subordinate part. In case of thunderstorms temporary storage on the surface level may, indeed, arise locally.

2.   Percolation into the ground water (saturated zone)
In a unpaved area, the precipitation will infiltrate into the topmost soil layer. This layer, the unsaturated zone, contains both water and air and is especially important to the vegetation. Moisture in this layer

may evaporate (evaporation) directly or indirectly, after absorption of moisture by vegetation (transpiration). Transpiration is the evaporation through the stomas of plants. This evaporation includes exclusively soil moisture, in quantities that are required for an optimum growth of the plant. If the amount of soil moisture is insufficient for this, this becomes the amount the plant is able to abstract. The total of evaporation and transpiration is evapotranspiration.

If the soil moisture is replenished to field capacity, the precipitation surplus will percolate into the ground water (percolation). By precluding shallow and poorly pervious layers (loamy soil, or intensive building) above the ground water surface, the infiltrated water may be drained over these layers (interflow). On low grounds part of the percolated water will be caught by drains and discharged to the drainage system.

In case of soil moisture shortage for vegetation (a soil water content below the field capacity), the soil moisture is replenished by capillary rise from the saturated zone. A condition in this case is that the ground water level is not too deep. In this way, part of the ground water becomes available again for transpiration or evaporation (Van Dam, 1985; Cultuurtechnisch Vademecum, 1988; Warmerdam, 1994).

3.   Ground water discharge into the drainage system
Characteristic for ground water discharge is a quelled runoff peak by means of horizontal and radial resistances in the ground. In case of deep ditches (complete ditches) the horizontal resistances dominate. Radial resistances dominate in case of incomplete ditches and drains. Due to relatively large resistances in the soil, extensive slowing down occurs (Van Dam, 1985).

Quick and slow ground water discharge processes
The runoff of precipitation may consist of a slow and a quick component (see figure 4 and 5). The part of the precipitation that is drained quickly, is the quick component. It may consist of the runoff of precipitation into open water, surface runoff, interflow and runoff originating from drainpipes.

quick ground water discharge

slow ground water discharge
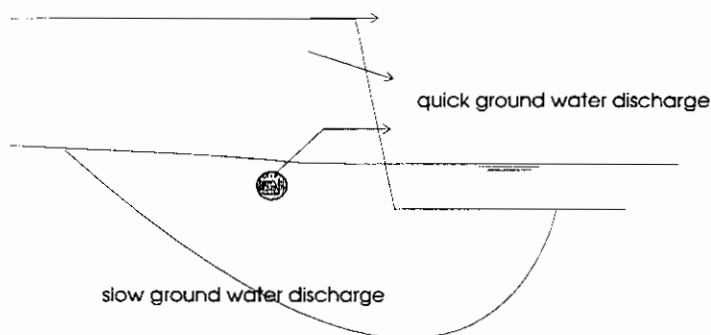
figure 4: Quick and slow components of ground water discharge
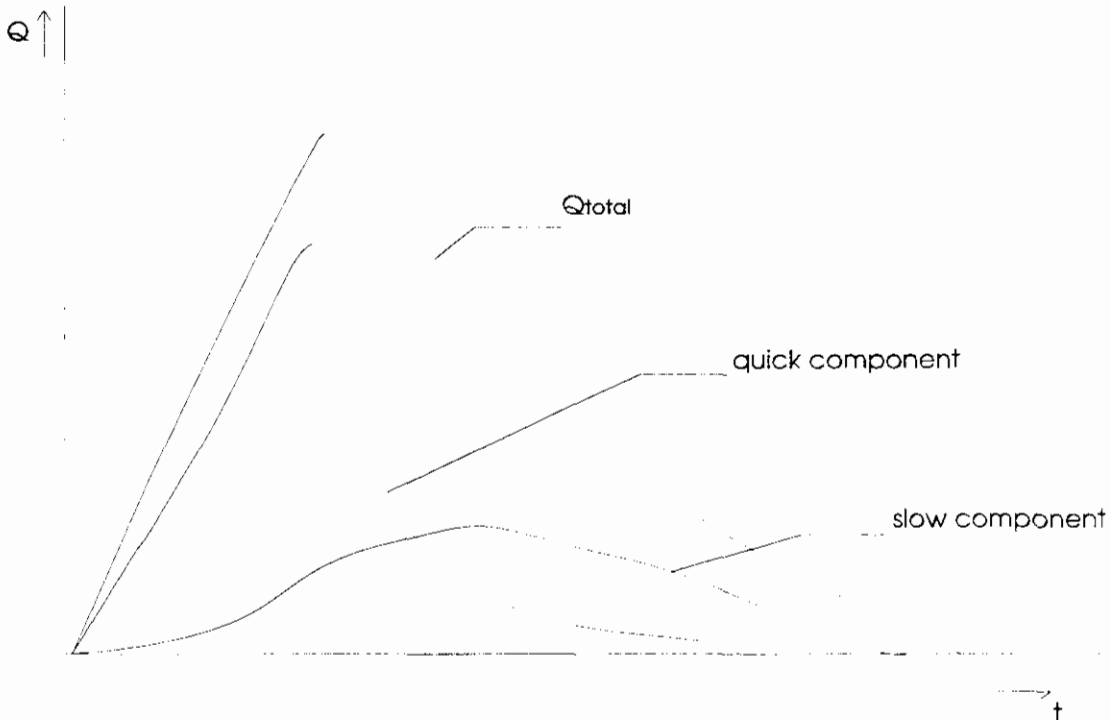
figure 5: Drainage course of quick and slow ground water discharge

The remaining effective precipitation is discharged quelled and slowed down to a relatively large extent, as a result of storage in the unsaturated and saturated zones (the slow component). The size of the unsaturated and saturated zones determines the degree of quelling and slowing down. A deep ground water level results in a large storage in the unsaturated zones. A large distance between the drainage ditches results in a large storage in the saturated zone. Also large, active pore volumes and a small horizontal transporting power result in a large storage in the saturated zone. The larger the storage and slowing down in the unsaturated and saturated zones, the more the discharge is slowed down and the discharge peak is quelled (Warmerdam, 1994).

Specific characteristics of runoff processes in The Netherlands
The precipitation runoff process in The Netherlands is generally characterized by low precipitation intensities and high infiltration capacities of the soil, in combination with slight slopes of the ground surface. This combination of factors results in runoff of the precipitation through the ground water for the greater part. Surface runoff occurs in a lesser degree.

In the Dutch situation, an intensive drainage system generally exists. The presence of open water creates extra storage capacity, which results in extra quelling and slowing down of the discharge course. The degree of quelling and slowing down depends on the pattern, the surface, the slope and the maintenance of water courses. In polder areas with a relatively high ground water level, the size of the active drainage system does not vary in accordance with the height of the ground water level. The thickness of the unsaturated zone is slight and the horizontal measurements of the ground water reservoir are constant, so that it may be expected that the total reservoir effect will be subject to only minor variations. In sloping areas increased fluctuations may, indeed, occur. This is comparable to a drainage characteristic (q-h relation). In polder areas a more or less linear relation exists, whereas in sloping areas a bended course occurs. The bends are used by increases in the active drainage system when the ground water level rises.

Generally speaking, the discharge course in an area is determined by a number of soil and terrain properties such as the size and the slope of the area, soil types, thickness and permeability of the aquifer, the storage capacity, land use and the nature and condition of the drainage system (Warmerdam, 1994).

2.1.1.3 Water balance

A general insight into the hydrologic cycle of a catchment area is obtained by setting up a water balance. A water balance for a catchment area has the following form:

Incoming terms = Outflowing terms + Change in storage in the area

When the time interval for which the water balance is set up amounts up to several years, the change in the storage of water may be neglected. Shorter time intervals are, however, required to determine the runoff, because the total change in the storage of water plays an important part in the relation between precipitation and discharge (see section 2.1.1.2).

The water balance for a catchment area is set up on the basis of figures 1 and 2. The incoming terms are the precipitation and the water inlets, the outgoing terms are the evapotranspiration and the water outlets. The total storage in a catchment area is built up by surface storage, open water storage and storage in the unsaturated zone and in the saturated zone.

The water balance worked out for a time interval is reflected below. In the left term the quantity of incoming terms are reflected; in the right term the outgoing terms and the change in the storage of water.

$$P + Q_i + K = Q_u + E + W + \Delta S$$

In which

P	: precipitation in mm
Q_i	: incoming flows in mm (originating from adjoining catchment areas)
Q_u	: outgoing flows in mm
K	: seepage in mm
E	: evapotranspiration in mm
W	: downward seepage in mm
ΔS	: change in storage in the catchment basin for the reflected time interval in mm

The above mentioned water balance is set up for a catchment area. In paragraph 2.1.1.2 a distinction is made between storage in the unsaturated zone and storage in the saturated zone. The water balance may be split up into unsaturated and saturated zones to determine both storage terms. This is reflected in figure 6.
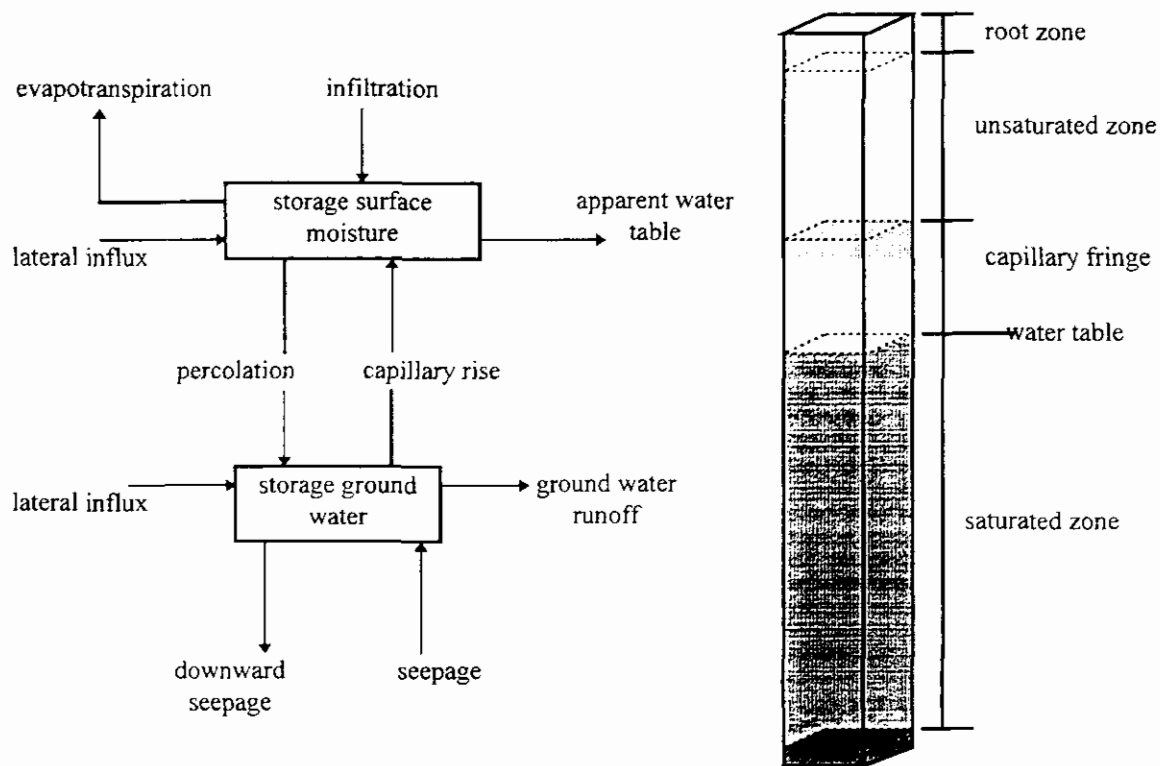
figure 6: Schematic overview terms water balance

Water balance unsaturated zone

The incoming terms of the unsaturated zone consist of infiltration, capillary rise from the saturated zone and lateral inflow. The outgoing terms are evapotranspiration, interflow and percolation to the saturated zone. The storage term is formed by storage in the unsaturated zone (soil moisture). The water balance set up for a selected time interval is:

$$Q_{\text{inf}} + Q_{capillary} + Q_{li} = Q_{percolation} + E + Q_{interflow} + \Delta S_{unsaturated}$$

In which

Q_{inf}	: infiltration in mm
$Q_{capillary}$	: capillary rise in mm
Q_{li}	: lateral inflow soil moisture in mm
$Q_{percolation}$	: percolation in mm
$Q_{interflow}$	: interflow in mm
$\Delta S_{unsaturated}$	: storage change in unsaturated zone for the reflected time interval in mm

Water balance saturated zone

The ingoing terms in the saturated zone consist of percolation from the unsaturated zone and lateral inflow. The outgoing terms consist of capillary rise to the unsaturated zone and seepage/downward seepage. The storage term is formed by the storage change in the ground water.

The water balance set up for a selected time interval is:

$$Q_{percolation} + Q_{li} = Q_{capillary} + K + W + \Delta S_{saturated}$$

In which:

$\Delta S_{saturated}$	: storage change in saturated zone for the reflected time interval in mm

Role of the water balance in description of precipitation runoff processes

Some terms of the water balance are input in precipitation runoff models (precipitation, water inlets, water outlets), other terms are calculated (evapotranspiration and ground water discharge).

The water balance is an important tool for calibration of precipitation runoff models. A precipitation runoff model is only capable to give a correct description of the precipitation runoff processes, if the water balance is described correctly. The calibration occurs by means of comparison of the effective precipitation with the summated effective discharge. Just one single term in the water balance is calibrated, rather than fitting on the total water balance. The water balance itself is used to verify the input values for the precipitation, water inlets and water outlets. In case of an inconsistent water balance, the input values will be reconsidered and corrected eventually.

2.1.2 Water Quality

In the precipitation runoff module the water quality part is limited for the time being to the description of the nitrogen and phosphor balance. Hoeks et al., 1990 was used for the description of the nitrogen and phosphor balances. In figure 7 the N- and P-balances are reflected schematically. A division was made into the supply, conversion processes in the soil and the drainage.
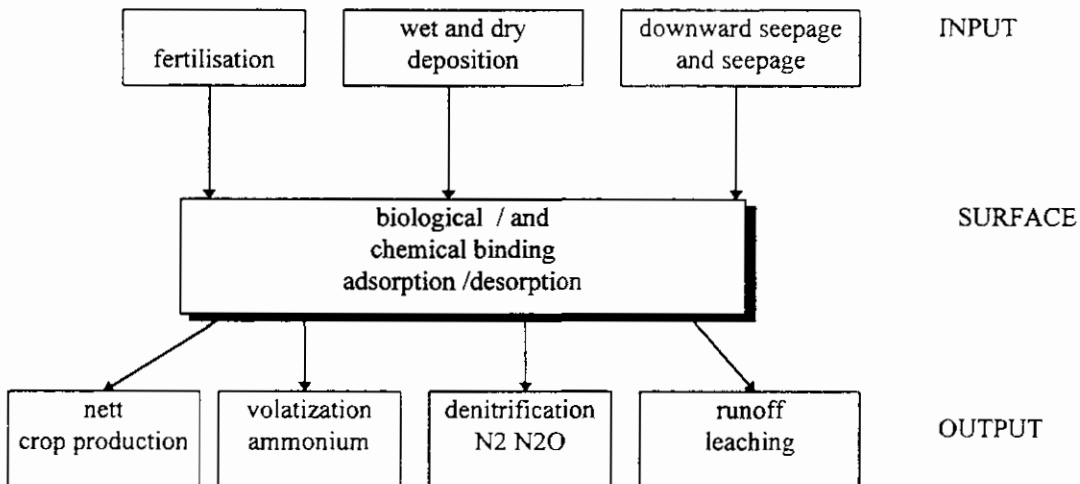
figure 7: N- and P-balances of a ground water system (Hoeks et al., 1990).

2.1.2.1 Supply

The supply consists of the items fertilization, deposition and seepage/downward seepage. The N- and P-load of the soil in The Netherlands in 1985 is listed in table 1 to illustrate the size of the various items.

Table 1: N- and P-load of the ground in The Netherlands in 1985 (Kroes et al., 1990)

	N-load (tons N/year)	P-load (tons P/year)
Total	1.069.000 (100%)	140.508 (100%)
Fertilization:	(87%)	(99%)
• Manure	(44%)	(74%)
• Fertilizer	(43%)	(25%)
Deposition:	(13%)	(<1%)
• Wet deposition	(5%)	
• Dry deposition	(8%)	
Seepage/downward seepage	<1%	<1%

Fertilization

From the overview above, it appears that fertilization, especially the degree and the way of fertilizing, plays an important part in the nitrogen and phosphor balances. The fertilization is bound by rules as recorded in the AMvB "Gebruik Dierlijke meststoffen" (Use of manure) of 1987. Fertilization mainly occurs during the growth season. The nitrogen in manure is deposited for about 70% onto grassland, 25% onto green maize plots and 5% onto other farmland. Nitrogen in artificial fertilizer is deposited for about 80% onto grassland and 20% onto other farmland (Kroes et al., 1990).

Deposition

The wet deposition consists of nitrogen supply through the precipitation. The "Landelijk Meetnet Regenkwaliteit" (National Measuring Network Rain Quality) (KNMI/RIVM) may be used to obtain data about the concentrations. Dry deposition consists of dust particles falling from the air onto the soil. The dry deposition is area-dependent.

Seepage/downward seepage

The contribution of seepage and downward seepage to the total P- and N-load in The Netherlands is very slight on average. Locally, this may, however, be an important resource, especially in North and South Holland.

2.1.2.2 Reaction processes in the soil

The reaction processes in the soil for nitrogen and phosphor are fundamentally different and are, therefore, treated separately.

Nitrogen

In the soil, nitrogen may exist in various forms and may be mutually converted into each other. Figure 8 shows a schematic overview of this.

FIXED   SOLVED   GAS

organic N in plant, manure, biomass → solving → N solved in organic material

mineralization   immobilization   mineralization

NH4-N to complex   adsorption / desorption   NH4-N   volatilization →   NH3-N

NO3-N   denitrification →   N2,N2O

leaching and runoff   to atmosphere
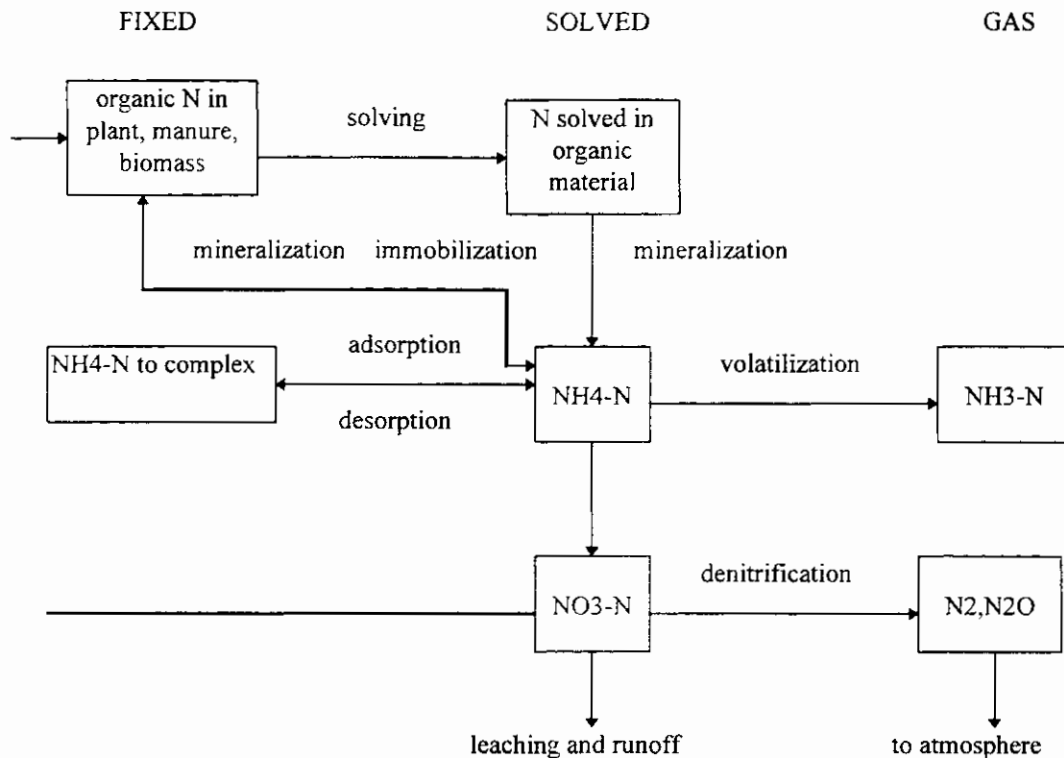
figure 8: Schematic overview of the nitrogen balance in the ground

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INTERMEZZO I: Illustration of N-balance in the soil

The presence of nitrogen in the soil may be subdivided into:
- Fixed nitrogen: as part of usually organic compounds, as part of plants, humus/biomass, or adsorbed to soil complexes.
- Solved nitrogen: especially ammonium and nitrate, also called mineral nitrogen. These are present in the soil, because of:
  - Supply of solvable nitrogen (see section 2.1.2.1)
  - Mineralization of N into a fixed substance, during which ammonium is formed.
    In the soil, ammonium is converted into nitrate by so-called nitrificating bacteria:

$$NH_1 + 2O_2 \rightarrow NO_3 + 2H^4 + H_2O \text{ (by Nitrobacter and Nitrosomas spp.)}$$
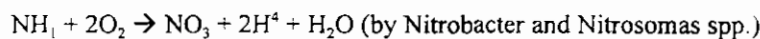
These bacteria have the following characteristics:
- They are aerobic; this means that they use oxygen in their metabolisms and, therefore are able to exist only under oxygen-rich conditions;
- They are autotrophic and use CO_2 as carbon source, instead of organic nitrogen compounds. This means that the nitrification is independent of the organic content in the soil. Nitrate is converted into N_2 by denitrifying bacteria in the soil.

Important characteristics of these bacteria are:
- Denitrification mainly occurs in an anoxic environment, this means in the absence of oxygen and in the presence of nitrate. Under these circumstances, nitrate instead of oxygen is used as donor of electrons in the metabolism of the bacterium;
- The bacteria are heterotrophic and require a carbon source, mainly short carbon chains. The fraction of organic matter in the soil and the mineralization degree of this, therefore, influences the denitrification.

Nitrification of the soil especially occurs in the oxygen-rich toplayer and denitrification occurs in the oxygen-poor bottomlayer (in anoxic layers in the saturated zone). The ground water level determines the availability of oxygen in the soil to a large extent.

Above the ground water table, more oxygen is present than under it. From modeling the catchment areas Beerse and Reusel, it appears that the nitrate concentration may rise to 100 mg NO_3-N/l in case of deep ground water levels, whereas the nitrate concentration is practically zero in case of high ground water levels. In addition to the ground water level, the organic content of the soil has an important influence on the nitrogen balance. High organic content lead to high conversion velocities, which causes the availability of oxygen in the ground to be exhausted quicker. In these circumstances, the denitrification will be predominant compared to the nitrification. In case of a low organic matter grade in the ground, this ratio is different.

With N-balance, microbiologic processes play an important part. Generally, microbiologic conversion processes are influenced by temperature, soil moisture content and pH. The discharge of nitrogen from the soil compartment is mainly determined by the type of soil, the ground water level and the ground use (among others: fertilizing).

Phosphor
Figure 9 shows a scheme of the phosphor balance in the soil.
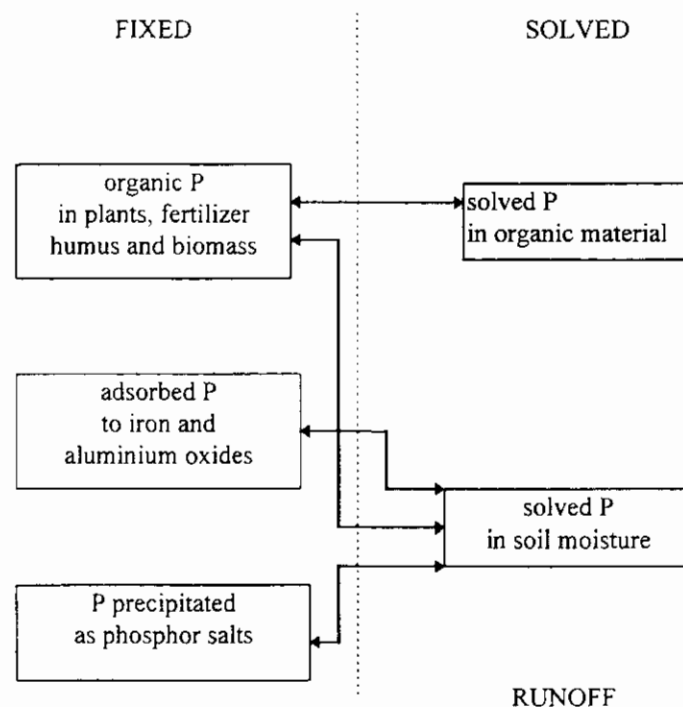
figure 9: phosphor balance in the ground

INTERMEZZO II: Illustration of P-balance in the ground

Phosphor in the soil may be subdivided into:

P in fixed substances
- P in biomass: The plants absorb phosphor for growing and incorporate it in the cell material of the plant. Also bacteria in the soil contain a fraction of phosphor;
- P adsorbed to iron and aluminium oxides. Many soil types have a significant phosphor fixation capacity, dependent on the structure and Fe and Al contents. The phosphor fixation capacity

differs per type of soil. The phosphor fixation capacity for clay soil is, for example, much higher than for sandy soil;
- The phosphor absorbs/complexes Al- and Fe-oxides in the soil. If the utilization degree of the phosphor fixation capacity is higher than 25%, it is phosphor saturated ground;
- P in precipitation: phosphate forms precipitations in the form of for example iron hydroxide complexes, calcium and barium phosphate;

P in solution
- Desorption of phosphor. P partly becomes solvable again due to desorption. The concentration is determined by the adsorption/desorption equilibrium in the soil. This equilibrium may be described by a so called normalized Freundlich isotherm (Kroes et al., 1990). The equilibrium depends on the P-content in the soil moisture, the phosphor fixation capacity and specific reaction velocity coefficients.
- Decomposition of organic matter. Due to rot of plant material, the fixed phosphor partly becomes solvable again.

Conclusions conversion processes nutrients
In summary, it may be posed that microbiologic processes play a main part in the nitrogen balance in the soil, whereas these are physical/chemical processes in the phosphor balance.
Important factors in the P-balance are:
- Type of soil (phosphor fixation capacity);
- Ground use (fertilization, utilization degree phosphor fixation capacity).
Import factors in the N-balance are:
- Ground water level;
- Organic matter content;
- Ground use (fertilization).

2.1.2.3 Discharge
The drainage of nutrients mainly occurs through the discharge of precipitation. In addition, nutrients disappear from the soil compartment due to absorption by plants. Discharge with water is usually subdivided in runoff (through surface runoff) and leaching (via ground water discharge).

Surface runoff (runoff)
In case of high water levels, or heavy precipitation, surface runoff may occur. Together with the rain water washing off, an amount of nutrients is directly discharged into the nearby surface water. This phenomenon may be reflected schematically in such a way that the rain water ends up in an imaginative surface reservoir, in which a complete mixing occurs (Kroes et al., 1990). In case of high precipitation intensities water will flow off from this place over the ground surface. Due to the reservoir effect, the concentration course of runoff is relatively constant during a small time scale. On a larger time scale, variations in the concentration course will occur, dependent on factors such as fertilization level and absorption by crops.

Ground water discharge (leaching)
In section 2.1.1.2 a number of components are distinguished, which form the ground water discharge. These are interflow, drainage-discharge and slow ground water discharge. The substances flow that is drained with this component is leaching. In practice, leaching is mainly determined by drainage-discharge.

Other drainage
Part of the nitrogen and phosphor is absorbed by plants and removed from the land during harvest. The fertilization policy in The Netherlands is aimed at an equilibrium between fertilization dose and nutrient absorption. In practice, however, this is most seldom the case. In most situations, surplus manuring occurs.

Drainage of the soil compartment also occurs through volatilization of ammonium. The share of volatilization has decreased significantly during the past few years, due to a change in the fertilization dose, such as injecting the fertilizer into grassland and ploughing in the fertilization on the farmland

within one day. Finally, nitrogen escapes from the ground in the form of N_2, which comes into being during denitrification (see section 2.1.2.2).

In table 2 an example of an N- and P-balance of the ground of intensively fertilized grassland unto the ground water level is reflected. It appears from this table that the total amount of nitrogen, which is circulating annually, is less than 10% of the total storage. This amounts to less than 3% for P. During discharge, the point of departure is a quick decomposition of mineral nitrogen that results in a reduction of 80-90% of the N.

Table 2: Example of N- and P-balance (kg/ha/year) of the soil unto the ground water level of intensively fertilized grassland (sand soil) (Drent 1994).

	Nitrogen		Phosphor	
	organic	mineral	organic	mineral
Supply				
animal fertilizer	185	185	20	80
artificial fertilizer	-	400	-	-
harvest losses	125	15	10	-
deposition	-	30	-	-
mineralization	-	250	1	1
Discharge				
volatilization	-	80	-	-
gross plant absorption	-	660	-	60
mineralization	250	-	20	-
denitrification	-	100	-	-
leaching and runoff	5	40	0,5	1
Accumulation	55	0	9,5	39
In root zone (kg/ha)	10.000	100	1.000	2.500

2.2 Translation Theory into General Set-up

The design of the precipitation runoff module is in line with the models that are applied in the Dutch situation, whenever possible. In addition, the most important bottlenecks in the current use have been solved in this design. During the design process, a survey was held among water boards to investigate which bottlenecks and wishes existed. The main conclusions of this investigation are:
- Linear reservoir models are applied frequently (De Zeeuw-Hellinga, Krayenhoff Van de Leur, De Jager or the Nash-cascade);
- Linear reservoir models start from the effective precipitation as input. The determination of the effective precipitation lacks from these models (the part of the precipitation that is actually discharged).

Based on these conclusions, the design includes a soil moisture reservoir for the determination of the effective precipitation, linked to a linear reservoir model for the description of the discharge course. In addition, a division into types of surface is made in view of the differences in precipitation runoff processes. For example, in case of a paved surface only a quick runoff process will occur, whereas an unpaved surface includes a slow component. By distinguishing between types of surface and between subprocesses, the framework of the precipitation runoff module is defined. In view of the objectives, the emphasis of the precipitation runoff module is at the description of the runoff processes of unpaved area. Figure 10 shows the framework of the precipitation runoff module

proces

Infiltration into the soil moisture

Percolation into the ground water

Ground water discharge into the drainage system

Leaching and runoff

| open water surface | paved surface | unpaved surface |

precipitation — precipitation — precipitation

open water evaporation — evaporation — soil moisture reservoir (evapotranspiration)

effective precipitation — effective precipitation — effective precipitation — surface runoff

slow component of the ground water discharge — quick component of the ground water discharge

direct — direct

seepage — seepage — seepage

discharge (open water) — discharge (paved surface) — discharge (unpaved surface)

concentration precipitation

concentration seepage

concentration discharge paved surface

concentration seepage

concentration slow component ground water discharge

concentration quick component ground water discharge

concentration precipitation

concentration seepage

figure 10: Framework of the precipitation runoff module

This chapter deals with the translation of the theoretical system description (see section 2.1) into the general set-up of the design (see section 2.3). It argues the choices which were made, which processes were included or excluded, which simplifications were made etc. This is worked out further in detail for each type of surface. Finally the set-up for the water quality part is worked out. Section 2.3 describes the technical design of the precipitation runoff module.

Open water surface
In open water losses are due to evaporation only. The effective precipitation is therefore simply calculated as precipitation minus the open water evaporation.

The hydrograph is described by means of a single linear reservoir, describing the effect of delay due to storage in the open water itself.

Paved surface
The losses occurring in case of paved surfaces, consist of moistening and evaporation of the wet surface. These losses have been put equal to the open water evaporation and will be minor in general.

In the description of the hydrologic cycle paved surface has been divided into (see section 2.1.1.1.):
• Paved surface in rural area;
• Urban area;
• Greenhouse area.

The discharge from paved surface is therefore divided into two subflows:
1. Paved surface discharging directly through the drainage system;

2   Surface discharging through a separated sewer system.

The discharge of paved surface in rural areas may be entered directly under subflow 1 (paved surface that discharges directly through the drainage system).

The discharge of urban areas occurs through the sewer system. The way of discharge is dependent on the type of sewer system. In case of a mixed sewer system, the precipitation is discharged in principle through sewage treatment plants. In case of extreme precipitation, part of the precipitation will be discharged into the surface water by means of overflow.
The effluent discharge of sewage treatment plants is measured in general. In the set-up of the precipitation runoff module this discharge is not included, but the point of departure is that it is entered directly into the flow model. This also applies to the discharge of overflows.

In case of a separated sewer system, the precipitation on paved surface will be discharged by the sewer system through the drainage system immediately. Part of the precipitation will be stored temporarily in the sewer system and on the paved surface. In general, specific models (Nationale Werkgroep Riolering en Waterkwaliteit, 1990 and Werkgroep Afvoerberekeningen [Workgroup discharge calculations], 1979) are used for the description of the discharge course. The output of these models may be used directly as input for the flow model.

In the precipitation runoff module an improved separated sewer system is treated equal to a separated sewer system. An improved sewer system can therefore be simulated identically.

The discharge from a separated sewer system is described in a sharply simplified way. The user is able to choose between:
•   Detailed application (calculate discharge from the sewer system by a specific model);
•   Simple applications (calculate discharge from the sewer system by the precipitation runoff module).

The choice between both applications will depend on the desired accuracy of the calculations and the presence of input data.

The discharge from greenhouse areas may be entered directly under subflow 2 (paved surface that discharges directly through the drainage system). With this, it is not possible to simulate a storage reservoir.

Unpaved surface
For the runoff processes of unpaved surface, three processes were distinguished in the precipitation runoff module (see section 2.1.1.2):
1.   Infiltration into the soil moisture (unsaturated zone)
2.   Percolation into the ground water (saturated zone)
3.   Ground water discharge into the drainage system.
These processes are distinguished in the precipitation runoff module also. This set-up is reflected in figure 11.

process A. Infiltration into the soil moisture

precipitation

surface discharge

infiltration   storage into the surface depressions
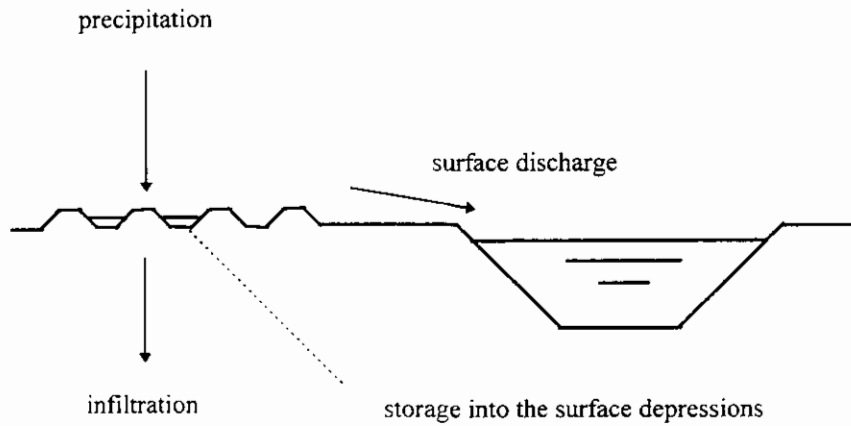
process B. Percolation into the ground water

infiltration   evapotranspiration

soil moisture content
pF = 0

actual soil
moisture content

soil moisture content
pF = 4.2

percolation

soil moisture reservoir

potential
evapotranspiration   evapotranspiration

percolation

percolation

2   4.2

pF - value

evapotranspiration and percolation relation
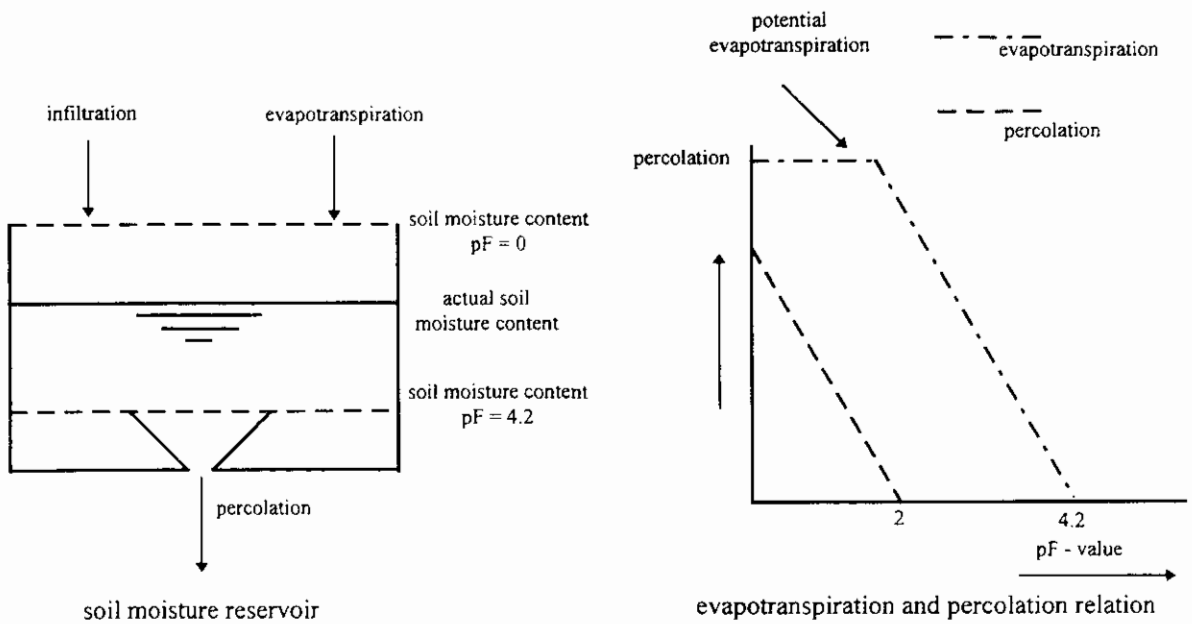
process C. Ground water discharge into the drainage system
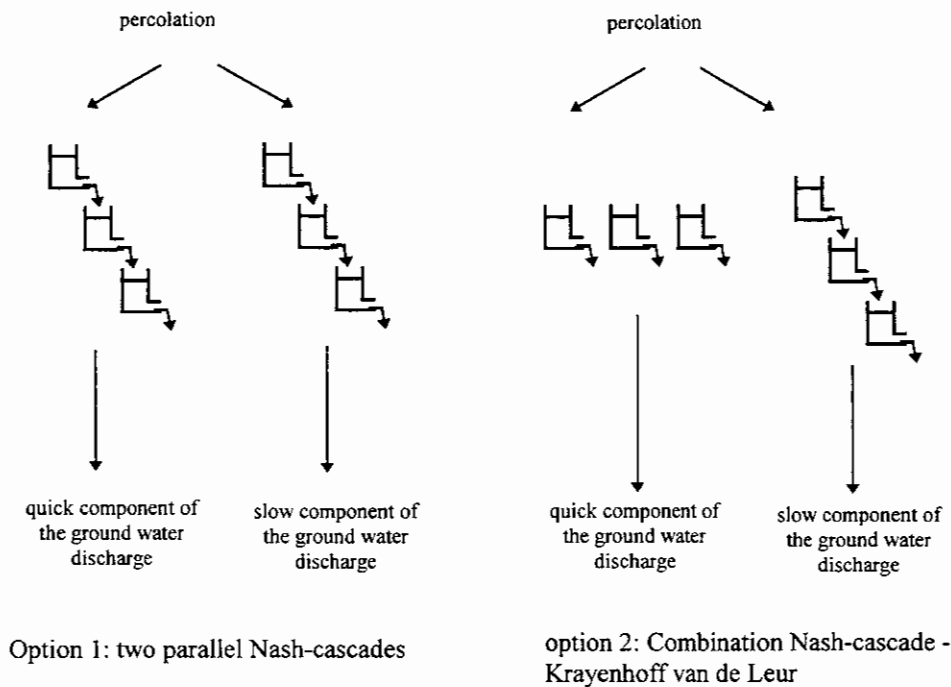
figure 11: Set-up runoff processes unpaved surface

1. Infiltration into the soil moisture (unsaturated zone)
The infiltration into the soil moisture is determined simultaneously to the processes as described in section 2.1.1.2. A water balance is worked out for the precipitation in surface depressions, where the precipitation is either infiltrating into the soil moisture or is discharged as surface runoff. The amount of precipitation that infiltrates is determined by the infiltration capacity of the soil, where the infiltration capacity is assumed constant in time. If the precipitation intensity surpasses the infiltration capacity, the remaining part of the precipitation will be stored on the surface level in the surface depressions. If the maximum storage in the surface depressions is surpassed, the extra precipitation will runoff over the surface as surface runoff.

2. Percolation into the ground water (saturated zone)
In the description of percolation into the ground water regarding the precipitation runoff module, a choice has been made between a physical-mathematical description of the processes and a description based on analogy of the occurring processes, without describing these exactly (conceptual models). The considerations made to arrive at the choice for the precipitation runoff model are addressed below in further detail.

The discharge of precipitation is determined by a number of input data (evapotranspiration and precipitation intensity) and by various soil and terrain properties of the catchment area (infiltration capacity, actual maximum and minimum moisture storage, the degree of drainage, presence of loamy layers, thickness of the unsaturated zone, etc.). Especially the soil and terrain properties may vary widely within a catchment area. These are not only dependent on the type of soil, but also on the ground use and the stage of growth. In addition, a number of parameters are often unknown (such as infiltration capacity). Therefore, it is not simple to translate these soil properties into area parameters.

Physical-mathematical models are based on a description of the occurring processes. Modeling these requires a vast amount of parameters to be entered. A large part of these parameters will, however, be unknown, and the translation into area values is difficult.

In order to steer clear of the above-mentioned problems, conceptual models are often used for precipitation runoff models. The models describe the 'hydrograph' rather then the real runoff processes. An example of a conceptual model is the Wageningen model. In this model the nature of the various processes is described ('soil moisture' reservoir for the storage in the unsaturated zone, convection-diffusion equation and model Krayenhoff van de Leur for the quick respective slow ground water runoff). The parameters in the model do not have a direct (measurable) physical meaning, but should be determined by calibration. In the model it has been attempted to limit the number of parameters, so that a set (as much as possible) independent parameters comes into existence.

It is important to distinguish between the various runoff processes (surface runoff, interflow, drainage and slow ground water discharge) for a correct description of the water quality. In physical-mathematical models this distinction is made, in conceptual models it is not made. It is remarked, however, that the various runoff processes cannot be measured separately, so that with regard to this aspect little significance may be attached to the results of a physical-mathematical model.

The point of departure in the development of the precipitation runoff module is a model for operational use (simple set-up with a limited number of input parameters). A physical-mathematical model requires extensive knowledge of the processes and a relatively large number of parameters need to be determined. Therefore, a conceptual model fits the point of departure of a precipitation drainage module for operational use (simple set-up) in a better way. For this reason a conceptual model was chosen for the precipitation runoff module. Hereby the point of departure is the soil moisture reservoir taken up in the Wageningen model. In addition, the adaptations proposed by the steering committee and the external experts have been included.

A water balance of the amount of moisture in the unsaturated zone is maintained in the soil moisture reservoir. The replenishment of soil moisture in the soil moisture reservoir is the calculated infiltration, the outflow is calculated as the evaporation and the percolation to the ground water (see figure 11). Both the evaporation and the percolation depend on the actual soil moisture content. The potential evapotranspiration is determined based on the reference crop evapotranspiration and a crop factor. If crops have not been supplied with water in an optimum way, the actual evapotranspiration is smaller than the potential evapotranspiration. The reduction is calculated by means of a linear relation between the evapotranspiration and the actual soil moisture content, where the actual evapotranspiration decreases form the potential evapotranspiration at field capacity towards zero at the wilting point. The percolation into the ground water also depends on the actual soil moisture content. This is described by means of a linear relation between the percolation and the actual soil moisture, where the percolation decreases form the maximal percolation at saturation towards zero at field capacity.

3. Ground water discharge into the drainage system.
Finally the effective precipitation will discharge as ground water into the drainage system. Due to the resistance of the soil for water flow, a significant slowing down effect will occur due to storage in the soil. Due to the similarity of the discharge processes with a delayed discharge due to the resistance in the soil, and a linear reservoir with a delayed discharge due to the resistance of the opening, this process is described by means of linear reservoir models. Besides the interflow and the drainage discharge, a quick and slow component were distinguished in the ground water discharge in the theoretical system description (section 2.1.1.2). This distinct was made because of the difference in characteristics of the processes and water quality. Both the quick and slow component of the ground water discharge can be defined as a configuration of linear reservoirs. Two options are incorporated in the precipitation runoff module:
1.   Two parallel Nash-cascades;
2.   Combination of Nash-cascade and Krayenhoff van de Leur.
In the first option, both the hydrograph of the quick and slow component are described by a number of linear reservoirs in series, a Nash-cascade. In the second option, the hydrograph of the quick component is described by means of a number of linear reservoirs parallel, Krayenhoff van de Leur, the slow component by means of a number of linear reservoirs in series, a Nash-cascade. Using both options, it is possible to simulate all widely applied models such as De Zeeuw-Hellinga, Krayenhoff van de Leur, Nash-cascade and De Jager. Varying the time constant of the reservoir and the number of reservoirs, the user can specify the model according to the application. For relatively quick discharge processes one reservoir with a small time constant of the reservoir will be sufficient, for a relatively

slow discharge process more reservoirs with a small time constant of the reservoir will give a better description.

Total runoff
In addition to the ground water runoff a term seepage is included. This is explained further in section 2.3.5. The total runoff of a catchment area consists of the discharge from the three types of surface and the term seepage:
- Open water ($Q_{open\ water}$);
- Paved surface (Q_{paved});
- Unpaved surface ($Q_{unpaved}$);
- Seepage (Q_{seep})

The drainage of unpaved surface consist of the runoff of the subflows:
- Surface runoff (Q_{sur});
- Quick component ground water discharge (Q_{quick});
- Slow component ground water discharge (Q_{slow});

Water quality
The composition of the discharged precipitation depends strongly on area-specific properties such as soil properties, degree and intensity of fertilization and land use. In practice, usually no measuring data per catchment area are available. An additional complication is that various subflows may be distinguished, which differ in flow rate and quality. Measuring data for each subflow regarding flow rates and composition should be available, in order to be able to draw a final picture of the quality. Possibly, it may be tried to determine a quality-flow rate relation for the drained precipitation. However, this requires an extensive and lengthy measuring program. Only few data are found in the literature.

An alternative for an intensive measuring campaign for surface water or subflows is the use of a model, in which the quality development of the drained precipitation is simulated based on a small number of input parameters. In the technical design a subflow approach has been worked out. It was tried to indicate a quality (development) for all the subflows, based on the literature. Target values are split up for type of land use and degree of fertilization. It was not possible to find 'target values' for all the subflows using this method. It is important to understand that this is about strongly simplified target values (possibly with bandwidths) with a certain inaccuracy. The user may decide whether it is possible to calculate with these in a sufficiently reliable way, or that a supplementary measuring campaign should be carried out.

Both solutions mentioned above include disadvantages. Measuring campaigns are expensive and compared to the required space and time, usually provide a very limited picture only. Models are a (strongly) simplified reflection of the reality, so that area-specific properties or essential processes may be lacking. In the precipitation runoff module a pragmatic model has been chosen as the solution. A big advantage of this is that water managers will receive a tool to obtain a first impression of the background values, also in case measuring data are lacking for the greater part and that they will be able to continue their model studies. Based on this tool, they will be able to decide for themselves whether the required reliability is fulfilled for the objective of the question. A comparison with the quality development of the receiving surface water can be made quickly, so that serious mistakes will be noticed. Should it appear that the precipitation runoff module differentiates to little in many cases, it may then be decided to carry out measuring campaigns until further notice.

Similar to the hydrograph it is strongly recommended to calibrate the model on measured concentration.

The runoff of nutrients of paved surface, organic fixed N is a main component (NWRW, 1986). This term has not been included in this version of RAM.

Remarks
Only part of the drainage system (primary canals) are included in the flow model. Within the catchment area defined, also a drainage system is present (secondary and tertiary canals). These

watercourses are indicated in the precipitation runoff module as 'open water surface'. The contribution of open water surface to the total runoff can be neglected in most situations, because it is only a small surface. But, the discharge from open water surface directly affects the water level.

As part of the schematisation, the user will define the catchment areas in the flow model. The precipitation runoff processes within a catchment area are determined by soil and terrain properties, such as slope and soil type (see section 2.1). The properties may, however, also vary strongly within the defined catchment area. The point of departure in the precipitation runoff module is that only the types of surface (open water, paved and unpaved surface) are distinguished. Within these surfaces, the catchment area is regarded as being homogeneous; the soil and terrain properties may be described as one (weighed) average value. The spatial variety within the defined catchment area is translated by the model's parameters. This implicates that the user him/herself is responsible for splitting up a catchment area, if a diversity of soil and terrain properties clearly exists.

In the model the runoff course is determined at the discharge point of a catchment area. Within a catchment area, however, also a drainage system is present. In case of large catchment areas, storage in the surface water may play a part. This is discounted in the linear reservoir.

The elements from the Wageningen model (Warmerdam, 1993) and the model BUIBAK (Hartman, 1994) are incorporated in the precipitation runoff module.

2.3 Formulas

2.3.1 General
Structure of technical design description
The technical design is worked out per type of surface. The types of surface distinguished are:
- Open water surface (section 2.3.2);
- Paved surface (section 2.3.3);
- Unpaved surface (section 2.3.4);
- Seepage (section 2.3.5).

After that, the technical design is worked out in further detail per subprocess for each type of surface. The subprocesses described in subsections are:
- Storage in unsaturated zone (determination of effective precipitation);
- Storage in saturated zone (determination of runoff course);
- Description of the water quality.

Time step
The user defines the time step in the precipitation runoff module, which remains constant during the calculation. It is recommended to use time steps similar to the time step used in input data as precipitation and evaporation, commonly given as 24 hour data.

Calculation discharge from linear reservoirs
The calculation of the runoff takes place in two steps. First the specific discharge (unit: [mm/day]) per time interval is calculated. Because the inputted precipitation intensity and reference vegetation evaporation applies to the preceding time interval, the specific discharge at point of time t is defined as the specific discharge during the time interval t-1 to t. In the second step, the specific discharge is converted to the momentanious discharge at the end of the time interval defined at point of time t (unit: $[m^3/s]$).

Definition precipitation and evaporation time interval
The daily observations of the KNMI are usually used for the precipitation intensity and the reference vegetation evaporation. The precipitation intensity and the reference crop evaporation are defined at time interval t from point in time t-1 to point in time t (the preceding time interval). The precipitation intensities provided by the KNMI are the intensities measured during the period from 08:00 hours on the preceding day to 08:00 hours on the day involved. The reference crop evaporation is the evaporation measured during a period from 24:00 hours on the preceding day to 24:00 hours on the day involved (KNMI, 1995).

Description Water Quality
The emphasis of the water quality is at the prediction of loads for ammonium (NH4), nitrate (NO3), and phosphor (PO4). The loads are determined as the products of the calculated discharges and the concentrations. The concentrations of the nutrients can be derived from the target values, as obtained from the literature. The target values are stated when found in literature, specified for land use, soil type and type of discharge, surface runoff, slow and quick component of the ground water discharge.

2.3.2 Open water surface

2.3.2.1 Determination of effective precipitation
The effective precipitation for open water is easy to determine. The losses are equal to the open water evaporation according to Penmann (GHO, 1988). The effective precipitation per time interval amounts to:

$$P_{N, open\_water, t} = P_{b,t} - f_0 E_{r,t} \qquad (1)$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	$E_{r,t}$	[mm/day]	Reference crop evaporation Makkink
Model parameters	f_0^*	[-]	Crop factor Makkink for open water
Output	$P_{N,open\_water,t}$	[mm/day]	Effective precipitation open water surface

*   The crop factor for open water is equal to E_0 / E_R in which E_0 is the open water evaporation according to Penmann. The factor varies somewhat but may approximately be equated with 1.25 (Cultuurtechnisch Vademecum, 1988)

During dry periods the open water evaporation is larger than the precipitation intensity. In this case a negative effective precipitation is calculated, which equals a precipitation shortage, simulating evaporation out of surface water in the drainage system.

2.3.2.2 Description of the Hydrograph

The drainage of the open water surface is determined by means of one linear reservoir.

$$q_{open\_water,t} = q_{open\_water,t-1}e^{-\Delta t / k_0} + P_{N,open\_water,t}(1 - e^{-\Delta t / k_0}) \qquad (2\text{-a})$$

$$Q_{open\_water,t} = aA_{open\_water}q_{open\_water,t} \qquad (2\text{-b})$$

Input	$q_{open\_water,t-1}^*$	[mm/day]	Specific discharge open water surface (formula 2-a)
	$P_{N,open\_water,t}$	[mm/day]	Effective precipitation open water surface (formula 1)
	A_{open_water}	[ha]	Open water surface
Model parameters	k_0	[day]	Time constant reservoir open water surface
	Δt	[day]	Time step
	a^{**}	[-]	Conversion factor units
Output	$Q_{open water,t}$	[m³/s]	Discharge open water surface

*   For $q_{open\_water,t-1}$ at point of time t = 0 a value of 0 is taken

**   The conversion factor is equal to 10/(24 * 3600)

Target values time constant
In practice, hardly any slowing down of the discharge through open water will occur. In this case a value of 0 may be taken as time constant. In relatively large catchment areas slowing down may, however, play a part. In this case a target value of 0.0014 à 0.002 days may be taken as time constant, in accordance with a time constant of paved surface (Cultuurtechnisch Vademecum, 1988).

2.3.2.3 Description water quality

Nitrogen

The nitrogen in the precipitation on open water forms a direct emission source to the water (the time interval between the precipitation supply and the precipitation drainage to the water is zero). This means that no processes occur that are able to influence the N-content in the meantime. The nitrate and ammonium loads through this flow to the canals may, therefore, be described in accordance with the zero order relation:

$$S_{NH4-N,open\_water,t} = Q_{open\_water,t} \times C_{NH4-N,precipitation,t} \qquad (3\text{-}a)$$

$$S_{NO3-N,open\_water,t} = Q_{open\_water,t} \times C_{NO3-N,precipitation,t} \qquad (3\text{-}b)$$

Input	$Q_{open\_water,t}$	[m³/s]	Discharge open water surface (formula 2-b)
Model parameters	$C_{NH4-N,precipitation,t}$ $C_{NO3-N,precipitation,t}$	[mg N/l] [mg N/l]	Ammonium-N concentration of precipitation Nitrate concentration of precipitation
Output	$S_{NH4-N,open\_water,t}$ $S_{NO3-N,open\_water,t}$	[g N/s] [g N/s]	Ammonium-N load of open water surface Nitrate load of open water surface

In the drainage system all sorts of processes occur, such as nitrification and denitrification, which influence the actual ammonium and nitrate contents in the canals. This aspect is described in the flow model and, therefore, is outside the scope of the precipitation runoff model.

In addition to nitrate and ammonium, also organic fixed nitrogen may be supplied with rain water. Rain water often contains a considerable amount of suspended solids. In this phase of the development, organic fixed nitrogen is, however, left out of consideration. Organic fixed nitrogen can be taken into account by the user in the concentration of the precipitation term.

Phosphor
The same assumptions as for nitrogen are applicable to phosphor. This means that the load is directly proportional to the flow. The phosphor load may, therefore, also be described in accordance with a zero order relation:

$$S_{P-total,open\_water,t} = Q_{open\_water,t} \times C_{P-total,precipitation,t} \qquad (4)$$

Input	$Q_{open\_water,t}$	[m³/s]	Discharge open water surface (formula 2-b)
Model parameters	$C_{P-total,precipitation,t}$	[mg P/l]	Phosphor concentration of precipitation
Output	$S_{P-total,open\_water,t}$	[g P/s]	Phosphor load of open water surface

Target values
The composition of rain water is reasonably known (Landelijk Regenwater meetnet [national rain water measuring network] of KNMI/RIVM). In table 3, the contents of ammonium, nitrate and total phosphor in the precipitation are reflected (v.d. Meent et al., 1985). From these figures extensive spread of the measuring values appears. Possibly more specific measuring data are available per location [A factor 0.014 applies to the conversion of μ mol/l to mg N/l].

Table 3: Overview of the average concentrations of precipitation (v.d. Meent et al, 1985)

	Ammonium-N (mg N/l)	Nitrate-N (mg N/l)	Phosphor (mg P-total/l)
Median	2.4	1.2	0.11
Minimum	1.3	0.90	0.06
Maximum	6.1	1.8	0.27

2.3.3 Paved surface

2.3.3.1 Determination effective precipitation

The losses occurring in case of paved surfaces, consist of moistening and evaporation of the wet surface. These losses have been put equal to the open water evaporation and will be minor in general.

$$P_{N,paved,t} = P_{b,t} - f_0 E_{r,t} \qquad \text{if} \qquad P_{b,t} \geq f_0 E_{r,t} \qquad (5\text{-a})$$

$$P_{N,paved,t} = 0 \qquad \text{if} \qquad P_{b,t} < f_0 E_{r,t} \qquad (5\text{-b})$$

Input	$P_{b,t}$ $E_{r,t}$	[mm/day] [mm/day]	Precipitation intensity Reference vegetation evaporation Makkink
Model parameters	f_0^*	[-]	Vegetation factor Makkink for open water
Output	$P_{N,paved,t}$	[mm/day]	Drainable precipitation paved surface

* The crop factor for open water is equal to E_0 / E_R in which E_0 is the open water evaporation according to Penmann. the factor varies somewhat but may approximately be equated with 1.25 (Cultuurtechnisch Vademecum, 1988)

2.3.3.2 Description of the Hydrograph

The discharge of paved surface is divided into two subflows:
1. Paved surface draining directly through the drainage system;
2. Surface draining through a separated sewer system.

The runoff of both subflows are determined with an singular linear reservoir. A singular linear reservoir was chosen because of the relatively short reaction time.

$$q_{sewer,t} = q_{sewer,t-1} e^{-\Delta t / k_s} + P_{N,paved,t}(1 - e^{-\Delta t / k_s}) \qquad (6\text{-a})$$

$$q_{paved,t} = q_{paved,t-1} e^{-\Delta t / k_p} + P_{N,paved,t}(1 - e^{-\Delta t / k_p}) \qquad (6\text{-b})$$

$$Q_{paved,t} = a(A_{sewer} q_{sewer,t} + A_{paved} q_{paved,t}) \qquad (6\text{-c})$$

Input	$q^{*}_{sewer,t}$	[mm/day]	Specific discharge separated sewer system (formula 6-a)
	$q^{*}_{paved,t-1}$	[mm/day]	Specific discharge paved surface (formula 6-b)
	$P_{N,paved,t}$	[mm/day]	Effective precipitation paved surface (formula 5)
	A^{**}_{sewer}	[ha]	Separated sewer surface
	A^{***}_{paved}	[ha]	Paved surface
Model parameters	k_s	[day]	Time constant reservoir separated sewer system
	k_p	[day]	Time constant reservoir paved surface
	Δt	[day]	Time step
	a^{****}	[-]	Conversion factor units
Output	$Q_{N,paved,t}$	[m³/s]	Discharge paved surface

*	For $q_{sewer,t-1}$ and $q_{paved,t-1}$ at point of time t = 0 a value of 0 is taken
**	Paved surface that discharges through a separated sewer system
***	Paved surface that discharges directly into open water
****	The conversion rate is equal to 10/(24 * 3600)

Target value time constant
The time constant is a measure of the velocity with which the precipitation is discharged . In case of paved surface a value of 0.0014 á 0.002 days is generally taken (Cultuurtechnisch Vademecum, 1988). If measured values are available, it is more accurate to derive the time constant from the tail course of the measured discharges. This concerns both the time constant for the reservoir for the separated sewer system as for the paved surface.

2.3.3.3 Description of water quality

Nitrogen
The discharge of paved surface originates from roofs and roads and is discharged through drain pipes or through a(n) (improved) separated sewer system into the drainage system. It is also applicable to this drainage that hardly any processes occur that influence the N-concentrations. The nitrogen load may, therefore, also be described in accordance with a zero order relation. However, it is indeed applicable to this drainage that organic fixed nitrogen may be a factor of importance. Therefore, an equation has been included for this. The discharge is described by the following formulas:

$$S_{NH4-N,paved,t} = Q_{paved,t} \times C_{NH4-N,paved,t} \tag{7-a}$$

$$S_{NO3-N,paved,t} = Q_{paved,t} \times C_{NO3-N,paved,t} \tag{7-b}$$

$$S_{org-N,paved,t} = Q_{paved,t} \times C_{org-N,paved,t} \tag{7-c}$$

Input	$Q_{paved,t}$	[m³/s]	Discharge paved surface (formula 6-c)
Model parameters	$C_{NH4-N,paved,t}$	[mg N/l]	Ammonium-N concentration runoff paved surface
	$C_{NO3-N,paved,t}$	[mg N/l]	Nitrate concentration runoff paved surface
	$C_{org-N,paved,t}$	[mg N/l]	Organic nitrogen in runoff paved surface
Output	$S_{NH4-N,paved,t}$	[g N/s]	Ammonium load of paved surface
	$S_{NO3-N,paved,t}$	[g N/s]	Nitrate load of paved surface
	$S_{org-N,paved,t}$	[g N/s]	Organic nitrogen in runoff paved surface

In the first version of the precipitation runoff module, the term organic fixed nitrogen has not been included.

Phosphor
Also for phosphor the concentration of the discharge may be taken as a constant. The timeframe between precipitation and discharge is short, so that the influence of reaction processes is zero.

$$S_{P,total,paved,t} = Q_{paved,t} \times C_{P-total,paved,t} \tag{8}$$

Input	$Q_{paved,t}$	[m³/s]	Discharge paved surface (formula 6-c)
Model parameters	$C_{P-total,paved,t}$	[mg P/l]	Phosphor concentration runoff paved surface
Output	$S_{P-total,paved,t}$	[g P/s]	Phosphor load of paved surface

Target values
The quality of the discharge from paved surface is determined to a large degree by the function of the area. The Nationale Werkgroep Riolering en Waterkwaliteit (1986) distinguishes the following main functions:
- Residential areas;
- Commercial areas (shops, offices, catering companies, secondary housing function);
- Roads;
- Industrial areas.

The quality of the discharged precipitation also depends on the type of sewer system. The water quality in case of an improved separated sewer system will be different from a separated sewer system. If the lower discharge amounts of improved separated sewer system are taken into account, it is acceptable to use the same target values for the concentrations.

The concentration of pollution in the discharge from paved surface fluctuates strongly. In table 4 the bandwidth between which the concentrations vary are indicated.

Table 4: Overview target value pollution concentrations runoff paved surface (Nationale Werkgroep Rioleringen en Waterkwaliteit, 1986)

	Residential Areas	Commercial Areas	Roads	Industrial Areas
Ammonium (mg N/l)	0.15-2.5	0.03	0.13-2.5	1.2-6.9
Nitrate (mg N/l)	0.1-0.7	0.2-0.5	0.28-1.4	5
Total Phosphate (mg P/l)	0.22-1.5	0.1-0.6	0.05-0.48	-
N-Kjeldahl (mg N/l)	1.5-3.6	0.7-1.1	0.68-5.1	1.2-200

2.3.4 Unpaved surface

For the runoff of unpaved surface, three processes were distinguished:
1. Infiltration into the soil moisture (unsaturated zone)
2. Percolation into the ground water (saturated zone)
3. Ground water discharge into the drainage system.

These processes are distinguished in the precipitation runoff module also. This set-up is reflected in figure 10.

2.3.4.1 Infiltration into the soil moisture (unsaturated zone)

First, the infiltration into the unsaturated zone is determined. In addition, the storage in the surface depressions and possibly occurring surface runoff are determined. These aspects are addressed below point by point:
- Infiltration;
- Storage in surface depressions
- Surface runoff

The amount of precipitation that infiltrates is determined by the infiltration capacity of the soil. If the precipitation intensity surpasses the infiltration capacity, the remaining part of the precipitation will be stored on the surface level in the surface depressions. If the maximum storage in the surface depression is surpassed, the extra precipitation will runoff over the surface (surface runoff).

Infiltration

In the design the point of departure is a constant infiltration capacity. This is further explained at the target values for the infiltration capacity. The infiltration intensity is calculated for the time interval from point of time t-1 to t. The precipitation intensity during the time interval is added to the storage existing in surface depressions at the start of the time interval (formula 9-a). When the precipitation intensity and the storage in the surface depressions surpasses the infiltration capacity, the infiltration capacity is set equal to the infiltration capacity (formula 9-b).

$$I_t = P_{b,t} + \frac{B_{t-1}}{\Delta t} \qquad \text{if} \qquad P_{b,t} + \frac{B_{t-1}}{\Delta t} \le I_{max} \qquad (9\text{-}a)$$

$$I_t = I_{max} \qquad \text{if} \qquad P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \qquad (9\text{-}b)$$

A specific situation occurs when the unsaturated zone approaches saturation. The maximum percolation out of the soil moisture reservoir instead of the infiltration capacity becomes critical for this situation (formula 9-c, see also section 2.3.4.2).

$$I_t = \Phi_{pF=0} - \Phi_{t-1} + P_{perc,max} \qquad \text{if} \qquad \Phi_{t-1} + I_t - P_{perc,max} > \Phi_{pF=0} \quad (9\text{-}c)$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	B_{t-1} *	[mm]	Storage in surface depressions (formula 10)
	I_{t-1} **	[mm/day]	Infiltration intensity (formula 9)
	Φ_{t-1} ***	[mm]	Actual moisture storage (formula 14)
Model Parameters	I_{max}	[mm/day]	Infiltration capacity
	Δt	[day]	Time step
	$P_{perc,max}$	[mm]	Percolation to the saturated zone at pF=0
	$\Phi_{pF=0}$	[mm]	Moisture storage if pF=0
Output	I_t	[mm/day]	Infiltration intensity

*   For B_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation without storage in surface depressions.

**   For I_{t-1} at point of time t=0, a value of 0 is taken, equalling a situation without infiltration.

***   For Φ_{t-1} at point of time t=0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined form the Staring Series).

Storage in the surface depressions
When the precipitation intensity surpasses the infiltration intensity, the water stays behind on the surface level and is stored in surface depressions. This storage in surface depressions depends strongly on the roughness of the ground. The storage at point of time t is determined with a water balance for the storage in surface depressions. For this purpose the precipitation intensity minus the infiltration intensity during time interval t-1 to t is added to the storage present in the surface depressions at the start of the time interval (point of time t-1). No water remains in the surface depressions when this volume is smaller than the infiltration capacity (formula 10-a). When this volume surpasses the infiltration capacity, water is stored in the surface depressions (formula 10-b). Surface runoff will occur when the amount in the surface depressions surpasses the maximum storage (formula 10-c).

$$B_t = 0 \qquad \text{if} \qquad P_{b,t} + \frac{B_{t-1}}{\Delta t} \leq I_{max} \qquad (10\text{-a})$$

$$B_t = (P_{b,t} - I_t)\,\Delta t + B_{t-1} \qquad \text{if} \qquad P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \text{ and} \qquad (10\text{-b})$$

$$\text{if} \qquad (P_{b,t} - I_t)\Delta t + B_{t-1} \leq B_{max}$$

$$B_t = B_{max} \qquad \text{if} \qquad P_{b,t} + \frac{B_{t-1}}{\Delta t} > I_{max} \text{ and} \qquad (10\text{-c})$$

$$\text{if} \qquad (P_{b,t} - I_t)\Delta t + B_{t-1} > B_{max}$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	I_t	[mm/day]	Infiltration intensity (formula 9)
	B_{t-1} *	[mm]	Storage in surface depressions (formula 10)
Model Parameters	I_{max}	[mm/day]	Infiltration capacity
	B_{max}	[mm]	Maximum storage in surface depressions
	Δt	[day]	Time step
Output	B_t	[mm/day]	Storage in surface depressions

*   For B_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation without storage in surface depressions

Surface runoff

The amount of precipitation that runs off as surface runoff, depends on the infiltration capacity of the soil, the precipitation intensity and the storage in surface depressions. When the amount of storage in surface depressions surpasses the maximum storage, surface runoff occurs.

$$P_{N,sur,t} = P_{b,t} + \frac{B_t}{\Delta t} - I_t - \frac{B_{max}}{\Delta t} \qquad \text{if:} \qquad \left(P_{b,t} - I_t\right)\Delta t + B_{t-1} > B_{max} \qquad (11\text{-a})$$

$$P_{N,sur,t} = 0 \qquad \text{if:} \qquad \left(P_{b,t} - I_t\right)\Delta t + B_{t-1} \le B_{max} \qquad (11\text{-b})$$

Input	$P_{b,t}$	[mm/day]	Precipitation intensity
	I_t	[mm/day]	Infiltration intensity (formula 9)
	B_{t-1} *	[mm]	Storage in surface depressions (formula 10)
Model Parameters	I_{max}	[mm/day]	Infiltration capacity
	B_{max}	[mm]	Maximum storage in surface depressions
	Δt	[day]	Time step
Output	$P_{N,sur,t}$	[mm/day]	Effective precipitation surface runoff unpaved surface

*   For B_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation without storage in surface depressions

In this section the effective precipitation for the surface runoff is described. The hydrograph is further described in section 2.3.4.3.

The evaporation from the surface depressions has not been included. The evaporation is indeed included as evapotranspiration from the unsaturated zone in the soil moisture reservoir. By neglecting the evaporation from surface depressions a slight error is introduced in general.

Target Values infiltration capacity

The velocity of infiltration depends on the intensity and the duration of the precipitation, type of soil, land use, and soil moisture content at the start of the shower. During a shower with a constant intensity, the infiltration velocity decreases exponentially from a maximum value f_0 at the start of the shower to an constant value f_c. This value is reached when the soil reaches the field capacity (see figure 12). Various formulas have been developed to determine the infiltration capacity of a type of soil.
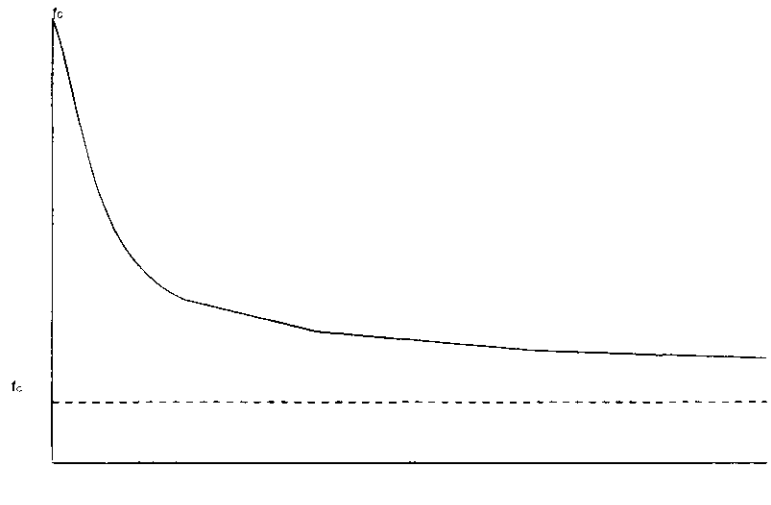
figure 12: Infiltration velocity

In the precipitation runoff module the precipitation runoff process is described at a catchment area level. An average value for the infiltration intensity in the catchment area will have to be entered. The infiltration intensity will, however, vary widely per location, due to variation in vegetation and type of soil. In addition, the infiltration intensity will vary in time and will decrease to a constant value when reaching the field capacity (pF = 2). Generally, the constant infiltration intensity as outlined in figure 12 will be reached within one day. This value is named as the infiltration capacity.

No infiltration formulas have been included in the precipitation runoff module. The user may enter an infiltration capacity for the catchment area involved, which is constant in time. The error introduced by this will be minor in case of time steps of one day or larger. Table 5 gives an overview of the values found in the literature.

Table 5: Target values infiltration capacity

Texture*	Infiltration capacity** after much rain
Sand (Wyseure and Feyen, 1982)	7.6-11.4 mm/hour
Finer texture	3.8-7.6 mm/hour
Very fine/disturbing layers	1.3-3.8 mm/hour
Impervious/clay with swelling	0.0-1.3 mm/hour
Saturated clay soil (BUIBAK, 1994)	approximately 4 mm/hour
Loamy and peaty soil	8 mm/hour
Very pervious sand	approximately 12 mm/hour

*   The texture classes are copied from the literature.
**   The infiltration capacity is expressed in [mm/day] instead of [mm/hour]

Target values maximum storage in surface depressions
The maximum storage in surface depressions depends on the roughness of the terrain and the degree of vegetation. Representative target values for the maximum storage in surface depression are difficult to give, in view of the wide variety of these parameters within areas. Based on the roughness and vegetation on the ground, an estimate will have to be made for this value. In general, the choice of this value will hardly influence the model results, because a situation in which the maximum storage in surface depressions occurs, hardly takes place in the Dutch situation.

2.3.4.2 Percolation into the ground water (saturated zone)

The percolation into the ground water is described by means of a soil moisture reservoir. A water balance of the amount of moisture in the unsaturated zone is maintained in the soil moisture reservoir.

The replenishment of soil moisture in the unsaturated zone or the inflow of the soil moisture reservoir is the infiltration calculated by the model. The outflows are the evapotranspiration and the effective precipitation (the precipitation that runs off through drains or ground water). The principle of the soil moisture reservoir is reflected in figure 11.

In the precipitation runoff module, capillary rise from the ground water to the unsaturated zone has not been included. Furthermore, it has been assumed that the infiltration immediately results in percolation. The occurring slowing down is ignored. This results in errors in the calculated evapotranspiration and the percolation.

Evapotranspiration relation

The potential evapotranspiration is determined based on the reference crop evapotranspiration and a crop factor. The crop factor is a measure for the transpiration of the crop and depends on the type of crop and the growth stage (function of time). If the crop has not been supplied with water in an optimum way, the actual evapotranspiration is smaller than the potential evapotranspiration. A simple relation between the actual evapotranspiration and the actual moisture storage is included (evapotranspiration relation). It has been assumed that in case of water contents larger than those in case of field capacity, the actual evapotranspiration is equal to the potential evapotranspiration. Between the moisture storage at field capacity and the wilting point, the actual evapotranspiration decreases linearly from the potential evapotranspiration at field capacity to zero at the wilting point. It has been assumed that no moisture is available to the vegetation at the wilting point.

$$E_{a,t} = f\, E_{r,t} \qquad\qquad \text{if} \qquad \Phi_{pF=0} \geq \Phi_{t-1} > \Phi_{pF=2} \qquad (12\text{-}a)$$

$$E_{a,t} = \frac{(\Phi_{t-1} - \Phi_{pF=4.2})}{(\Phi_{pF=2} - \Phi_{pF=4.2})}\, f\, E_{r,t} \qquad \text{if} \qquad \Phi_{pF=2} \geq \Phi_{t-1} \geq \Phi_{pF=4.2} \qquad (12\text{-}b)$$

$$E_{a,t} = 0 \qquad\qquad \text{if} \qquad \Phi_{t-1} < \Phi_{pF=4.2} \qquad (12\text{-}c)$$

Input	Φ_{t-1} *	[mm]	Actual moisture storage (formula 14)
	$E_{r,t}$	[mm/day]	Reference crop evapotranspiration Makkink
Model Parameters	$\Phi_{pF=2}$	[mm]	Moisture storage if pF=2
	$\Phi_{pF=4.2}$	[mm]	Moisture storage if pF=4.2
	f	[-]	Crop factor Makkink
Output	$E_{a,t}$	[mm/day]	Actual evapotranspiration

*   For Φ_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined from the Staring series)

Percolation relation

The percolation to the ground water depends on the water content in the unsaturated zone. In the precipitation runoff module, a simple relation between the percolation and the actual moisture storage (percolation relation) has been included. It has been assumed that in case of saturation, the percolation is equal to the maximum percolation. Between the moisture storage saturation and at field capacity, the percolation decreases linearly from the maximum percolation at saturation to zero at field capacity. It has been assumed that no moisture is available for percolation at the wilting point.

$$P_{perc,t} = \frac{(\Phi_{t-1} - \Phi_{pF=2})}{(\Phi_{pF=0} - \Phi_{pF=2})} P_{perc,max} \qquad \text{if} \quad \Phi_{pF=0} \geq \Phi_{t-1} > \Phi_{pF=2} \qquad (13\text{-}a)$$

$$P_{perc,t} = 0 \qquad\qquad\qquad\qquad \text{if} \quad \Phi_{t-1} \leq \Phi_{pF=2} \qquad\qquad (13\text{-}b)$$

Input	$\Phi_{t-1}{}^{*}$	[mm]	Actual moisture storage (formula 14)
	I_t	[mm/day]	Infiltration intensity (formula 9)
Model Parameters	$\Phi_{pF=0}$	[mm]	Moisture storage if pF=0
	$\Phi_{pF=2}$	[mm]	Moisture storage if pF=2
	$\Phi_{pF=4.2}$	[mm]	Moisture storage if pF=4.2
	$P_{perc,max}$	[mm/day]	Percolation to the saturated zone that occurs between pF=0 and pF=2 (maximum)
Output	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone

* For Φ_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined from the Staring series)

Water balance soil moisture reservoir
In the water balance, both the evaporation and the percolation depend on the actual soil moisture content. The change in the soil moisture content is described with the differential equation:

$$\frac{\partial \Phi}{\partial t} = I_t - E_{a,t}(\Phi) - P_{perc,t}(\Phi)$$

The equation is solved explicitly. At point of time t-1 the condition of the soil moisture reservoir is expressed in the moisture storage Φ_{t-1}. Based on the actual moisture storage at point of time t-1, the evapotranspiration and percolation are calculated for the time interval from point of time t-1 to t. Based on the calculated evapotranspiration and percolation, the actual moisture storage at point of time t is calculated (Φ_t)

$$\Phi_t = \Phi_{t-1} + (I_t - E_{a,t} - P_{perc,t})\Delta t \qquad\qquad\qquad (14)$$

Input	$\Phi_{t-1}{}^{*}$	[mm]	Actual moisture storage (formula 14)
	I_t	[mm/day]	Infiltration intensity (formula 9)
	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 13)
	$E_{a,t}$	[mm/day]	Actual evapotranspiration (formula 12)
Model Parameters	Δt	[day]	Time step
Output	Φ_t	[mm]	Actual moisture storage

* For Φ_{t-1} at point of time t = 0, a value of 0 is taken, equalling a situation with field capacity pF=2 (to be determined from the Staring series)

Disadvantage of an explicit solution is the risk of instable calculations, occurring with large time steps or a relatively small content of the soil moisture reservoir. In case of instable calculation, the user should define smaller time steps.

The moisture storage in the soil moisture reservoir varies between the minimal moisture storage at wilting point and the maximal moisture storage at saturation. For moisture storage values smaller than at wilting point, no evaporation occurs (formula 12-c), for values larger than the at saturation the percolation is set equal to the infiltration capacity (formula 13-a).

Target values crop factor Makkink
The crop factor depends on the type of overgrowth and the growth stage. In appendix I an overview is given of the crop factors for various crop types. The crop factor for a catchment area is determined as the mean crop factor per percentage of the surface for the different crops in the catchment area.

Target values moisture storage
In the formulas 13 and 14, the moisture storage at field capacity (pF=2) and at the wilting point (pF=4.2) need to be entered. The moisture storage in the unsaturated zone is derived from the soil moisture content and the location of the ground water level compared to the surface level. It is remarked that the moisture storage depends on the location of the ground water level. In polder areas slight fluctuations in the ground water level occur in general. In sandy soils more fluctuations occur, so that also the moisture storage will vary.

In the Staring series, the soil moisture characteristics for various types of soils are determined. This is a relation between the pF value (logarithm of the negative pressure head) and the soil moisture content. Based on the Staring series, the water content at field capacity and at the wilting point may be determined for the various types of soils. In appendix II a summary of the Staring series is given.

Therefore, the following method may be used to determine the moisture storage:
- The length between the average surface level and the average ground water level or water level in the drainage system is estimated. This length is assumed being constant during the simulation period (for example 0.8 m);
- The soil moisture content is determined for the dominating type of soil at saturation level (pF=0), at field capacity level (pF=2) and at the wilting point (pF=4.2). These values are recorded in the Staring series (see appendix II) for the most common types of soil. As an example, the values for 'loamy-poor, very fine to moderately fine sand' are 37.1 volume percent (pF=0), 20.1 volume percent (pF=2) and 3 volume percent (pF=4.2).
- The moisture storage is determined as the product of the length of the unsaturated zone and the volume fraction. In the example above this would be:
  - $\Phi_{pF=0} = 0.371 \times 0.8m = 296.8mm$
  - $\Phi_{pF=2} = 0.201 \times 0.8m = 160.8mm$
  - $\Phi_{pF=4.2} = 0.003 \times 0.8m = 24mm$

target value maximum percolation
The maximum percolation is the percolation at saturation. Mostly the infiltration capacity is taken as target value for the maximal percolation. Table 5 gives an overview of the target values for the infiltration capacity.

2.3.4.3 Ground water discharge into the drainage system

The discharge from unpaved surface is built up by various runoff processes. The interflow and the drainage have not been described separately, but jointly form the quick ground water runoff. Within the design the following aspects are distinguished:

- Surface runoff;
- Quick component of the ground water discharge;
- Slow component of ground water discharge.

Surface runoff

This discharge is described with one linear reservoir, equal to the description for discharge of open water (the discharge of the water across the surface level to open water takes place relatively quickly).

$$q_{sur,t} = q_{sur,t-1} e^{\frac{-\Delta t}{k_{sur}}} + P_{N,sur,t}(1 - e^{\frac{-\Delta t}{k_{sur}}})$$
(15-a)

$$Q_{sur,t} = a\, A_{unpaved}\, q_{sur,t}$$
(15-b)

Input	$q_{sur,t-1}^{*}$	[mm/day]	Specific surface runoff unpaved surface (formula 15-a
	$P_{N,sur,t}$	[mm/day]	Effective precipitation surface runoff unpaved surface (formula 11)
	$A_{unpaved}$	[ha]	Unpaved surface
Model Parameters	k_{sur}	[day]	Time constant reservoir surface runoff unpaved surface
	Δt	[day]	Time step
	a^{**}	[-]	Conversion factor units
Output	$P_{sur,t}$	[m³/s]	Surface runoff unpaved surface

*   For $q_{sur,t-1}$ at point of time t = 0, a value of 0 is taken

**   The conversion factor is equal to 10/(24 * 3600)

Target value time constant

The time constant is a measure for the velocity with which the precipitation is discharged. The surface runoff will take place very quickly. As target value a value of 0.0014 á 0.002 days may be taken, equalling the time constant of paved surface (Cultuurtechnisch Vademecum, 1988).

Quick and slow component of the ground water discharge

During the discharge through the saturated zone, a significant slowing down effect occurs because of resistances in the soil. This process is described by a configuration of linear reservoirs. The quick and slow component of the ground water discharge are described by separate linear reservoirs, of which two possibilities are taken up.

- (a) Two parallel Nash-cascades;
- (b) Combination of Nash-cascades and Krayenhoff van de Leur

ad (a) two parallel Nash-cascades

In this option, the discharge is divided into a quick and a slow component ground water runoff by means of a distribution code. The percolation calculated will partly runoff through a slow component (βP_{perc}) and partly through a quick component ($[1-\beta]P_{perc}$). The hydrographs of both the quick and slow ground water discharge are described by a series of linear reservoirs (see figure 11). By entering the time constant and the number of reservoirs, the user may enter the properties of the

discharge process. In the precipitation runoff module, a default value of one has been taken for the number of reservoirs.

The quick and slow ground water discharges are described by the following formulas:

For the 1ˢᵗ reservoir:

$$q_{quick,1,t} = q_{quick,1,t-1} \, e^{\frac{-\Delta t}{k_q}} + (1-\beta)P_{perc,t} \, (1 - e^{\frac{-\Delta t}{k_q}})$$ (16-a)

For i is the 2ⁿᵈ unto and including the mᵗʰ reservoir:

$$q_{quick,i,t} = q_{quick,i,t-1} \, e^{\frac{-\Delta t}{k_q}} + q_{quick,i-1,t} \, (1 - e^{\frac{-\Delta t}{k_q}})$$ (16-b)

For the 1ˢᵗ reservoir:

$$q_{slow,1,t} = q_{slow,1,t-1} \, e^{\frac{-\Delta t}{k_s}} + \beta P_{perc,t} \, (1 - e^{\frac{-\Delta t}{k_s}})$$ (16-c)

For i is the 2ⁿᵈ upto and including the nᵗʰ reservoir:

$$q_{slow,i,t} = q_{slow,i,t-1} \, e^{\frac{-\Delta t}{k_s}} + q_{slow,i-1,t} \, (1 - e^{\frac{-\Delta t}{k_s}}) \}$$ (16-d)

$$Q_{quick,t} = a \, A_{unpaved} \, q_{quick,m,t}$$ (16-e)

$$Q_{slow,t} = a \, A_{unpaved} \, q_{slow,n,t}$$ (16-f)

Input	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 13)
	$q_{slow,i,t-1}^{*}$	[mm/day]	Specific slow component ground water discharge unpaved surface (formula 16)
	$q_{quick,i,t-1}^{*}$	[mm/day]	Specific quick component ground water discharge unpaved surface (formula 16)
	$A_{unpaved}$	[ha]	Unpaved surface
Model Parameters	β	[-]	Distribution code quick and slow components ground water discharge
	k_s	[day]	Time constant reservoir slow component ground water discharge
	k_q	[day]	Time constant reservoir quick component ground water discharge
	m	[-]	Number of reservoirs quick component ground water discharge
	n	[-]	Number of reservoirs slow component ground water discharge
	Δt	[day]	Time step
	a^{**}	[-]	Conversion factor units

Output	$Q_{slow,t}$	[m³/s]	Drainage slow component ground water discharge
	$Q_{quick,t}$	[m³/s]	Drainage quick component ground water discharge.

ad (b) combination Nash-cascade and Krayenhoff van de Leur

In this option the discharge is also divided into a quick and a slow component ground water discharge, by means of a distribution code. The hydrograph of the quick ground water discharge is described in this option by a number of parallel linear reservoirs (Krayenhoff van de Leur). The slow ground water runoff is described by a series of linear reservoirs (see figure 11). A default value of one has been taken for the number of reservoirs in a series.

The quick and slow components of the ground water discharge is described by the following formulas:

For i is the 1st unto and including the dth reservoir:

$$q_{quick,i,t} = (1-\beta) * \left\{ \frac{1}{(\sum\limits_{j=1,3,5...j^2}^{(2d-1)} \frac{1}{j^2})} P_{perc,t} \frac{1}{(2i-1)^2} (1-e^{\frac{-\Delta t(2i-1)^2}{k_q}}) \right\} + q_{quick,i,t-1} e^{\frac{-\Delta t(2i-1)^2}{k_q}}$$

(17-a)

For the 1st reservoir:

$$q_{slow,1,t} = q_{slow,1,t-1} e^{\frac{-\Delta t}{k_s}} + \beta P_{perc,t} (1-e^{\frac{-\Delta t}{k_s}})$$ (17-b)

For i is the 2nd upto and including the nth reservoir:

$$q_{slow,i,t} = q_{slow,i,t-1} e^{\frac{-\Delta t}{k_s}} + q_{slow,i-1,t}(1-e^{\frac{-\Delta t}{k_s}})$$ (17-c)

$$Q_{quick,t} = a A_{unpaved} (\sum\limits_{i=1}^{d} q_{quick,i,t})$$ (17-d)

$$Q_{slow,t} = a A_{unpaved} q_{slow,n,t}$$ (17-e)

Input	$P_{perc,t}$	[mm/day]	Percolation into the saturated zone (formula 13)
	$q_{slow,i,t-1}$ *	[mm/day]	Specific slow component ground water discharge unpaved surface (formula 17)
	$q_{quick,i,t-1}$ *	[mm/day]	Specific quick component ground water discharge unpaved surface (formula 17)
	$A_{unpaved}$	[ha]	Unpaved surface

Model Parameters	β	[-]	Distribution code quick and slow components ground water discharge
	k_s	[day]	Time constant reservoir slow component ground water discharge
	k_q	[day]	Time constant reservoir quick component ground water discharge
	d^{**}	[-]	Number of reservoirs quick component ground water discharge
	n	[-]	Number of reservoirs slow component ground water discharge
	Δt	[day]	Time step
	a^{***}	[-]	Conversion factor units
Output	$Q_{slow,t}$	[m³/s]	Discharge slow component ground water discharge
	$Q_{quick,t}$	[m³/s]	Discharge quick component ground water discharge.

*   For $q_{slow,i,t-1}$ and $q_{quick,i,t-1}$ at point of time t = 0, a value of 0 is taken for all reservoirs i=1 - n and i=1- m

**   The Krayenhoff van de Leur model describes an infinite number of reservoirs. This is discreticised to a finite number of reservoirs. Each next reservoir empties quicker and processes a smaller part of the precipitation. The target value for the number of reservoirs is 5 reservoirs.

***   The conversion factor is equal to 10/(24 * 3600)

Target values time constant
The target values for the time constant of linear reservoirs are derived from measured hydrographs. The target values for the Krayenhoff van de Leur model are given in table 6. Since catchment areas are mostly not homogeneous, the time constant can be calculated as the weight mean time constant per percentage of the surface.

The target values as presented in table 6 can not be used at once. The precipitation runoff module is extended compared to the Krayenhoff van de Leur model. It distinguishes paved and unpaved surface, so the time constant is specified for each type of surface, where the time constant for the unpaved surface only describes the discharge processes for unpaved surface. The time constant in the Krayenhoff van de Leur model only describes the full surface (paved and unpaved surface). In addition, the precipitation runoff model describes part of the slowing down in the soil moisture reservoir. This has consequences for the time constant to be used for the linear reservoirs. The target values can therefore be used as start values, but calibration of the values with measured discharges remains essential.

An other way to derive the time constant is from measured hydrographs. This is the most direct and accurate way to estimate the time constant. In addition, the time constant of both the quick and slow component of the ground water discharge can be estimated separately. The quick component is estimated from the hydrograph of discharge peaks, whereas the slow component is estimated from the hydrograph during low discharges.

Table 6: Target values for the Krayenhoff van de Leur model

k [days]	Drainage type
0.0014 - 0.002	Discharge of 1000-4000 m² paved surface
0.005 - 0.01	Surface runoff on strongly sloping ground
0.1 - 1	Surface runoff, runoff of grounds with impervious layers at a very shallow depth
1.5 - 3	Runoff of well-drained farmland
15 - 30	Badly drained grassland with overgrown ditches (swamp runoff)
300 - 2000	Discharge of seepage from high, very pervious grounds (Veluwe, Zuid-Limburg)

Target values configuration linear reservoirs

The precipitation runoff module distinguishes a quick and slow component of the ground water discharge. The user defines the number of reservoirs and the distribution code related to the application.

For rather simple applications, it is not particularly necessary to distinguish a quick and slow component of the ground water discharge. The ground water discharge is described by a single component with a single linear reservoir and a value for the distribution factor of 0 or 1.

For more detailed applications, however, it is recommended to distinguish a quick and slow component of the ground water discharge. It is not possible to give target values for the distribution factor. This factor should therefore be calibrated on measured hydrographs simultaneously to the time constants (see target values time constant).

In the Nash-cascade, the number of reservoirs in series must be entered. The default is one reservoir. In case of large catchment areas, extra travel time may be created by entering several reservoirs.

The model Krayenhoff van de Leur theoretically describes an infinite number of reservoirs. In the precipitation runoff module, the model is discreticised into a finite number of reservoirs, in which each next reservoir empties quicker but processes a smaller part of the precipitation. In case of a number of reservoirs of 5, the error introduced is negligible.

2.3.4.4 Description water quality

The description of the water quality is based on the discharge processes distinguished for the determination of the hydrograph, surface runoff, quick and slow component of discharge (see section 2.3.4.2).

1.   Surface runoff

Nitrogen

The surface runoff is formed by precipitation that runs off directly across the surface level. In this case, reaction processes occur to a lesser degree. Therefore, the load is described by an a zero order relation.

$$S_{NH4-N,sur,t} = Q_{sur,t} * C_{NH4-N,sur,t} \qquad (18\text{-}a)$$

$$S_{NO3-N,sur,t} = Q_{sur,t} * C_{NO3-N,sur,t} \qquad (18\text{-}b)$$

$$S_{org-N,sur,t} = Q_{sur,t} * C_{org-N,sur,t} \qquad (18\text{-}c)$$

Input	$Q_{sur,t}$	[m³/s]	Surface runoff unpaved surface (formula 15-b)
Model Parameters	$C_{NH4-N,sur,t}$	[mgN/l]	Ammonium-N concentration surface runoff unpaved surface
	$C_{NO3-n,sur,t}$	[mg N/l]	Nitrate concentration surface runoff unpaved surface
	$C_{org-N,sur,t}$	[mg N/l]	Organic nitrogen concentration surface runoff unpaved surface
Output	$S_{NH4-N,sur,t}$	[g N/s]	Ammonium load surface runoff unpaved surface
	$S_{NO3-N,sur,t}$	[g N/s]	Nitrate load surface runoff unpaved surface
	$S_{org-N,sur,t}$	[g N/s]	Organic nitrogen load surface runoff unpaved surface

In the first version of the precipitation runoff module the term organically fixed nitrogen has not been included.

Phosphor
The phosphor load is described by a zero order equation just as nitrogen.

$$S_{P-total,sur,t} = Q_{opp,t} * C_{P-total,sur,t} \tag{19}$$

Input	$Q_{sur,t}$	[m³/s]	Surface runoff unpaved surface (formula 15-b)
Model Parameters	$C_{P-total,sur,t}$	[mg P/l]	Phosphor concentration surface runoff unpaved surface
Output	$S_{P-total,sur,t}$	[g P/s]	Phosphor load surface runoff unpaved surface

Target values
Only few target values are known for the concentrations of surface runoff. The concentration depends very much on the time scale and the ground use. During a longer period, this concentration will approach that of the precipitation. On a small time scale, ground use and fertilisation level are determining factors. The target values as obtained form the literatue are listed in table 7.

2.   Quick component of the ground water discharge
The quick ground water discharge consists of precipitation, which is discharged through drain pipes, after infiltration into the ground (see figure 4). Contrary to the slow ground water discharge, this precipitation is buffered to a less degree, before it is discharged. The concentration nutrients is, therefore, often higher and there is more fluctuation.

In case of leaching of nutrient loads, it is relevant to distinguish between various types of ground use, especially between fertilised and non-fertilised surfaces. In case of non-fertilised surfaces the nutrient concentrate profile is much flatter in the vertical direction than in case of fertilised surfaces.

Nitrogen
A factor of influence is the flow rate of effective precipitation. The key question is whether the precipitation can lead to such a thinning that in case of much precipitation, the concentration decreases substantially. In the intermezzo below, a calculation model is worked out, in which is concluded that the influence of the precipitation flow rate has little effect on the N-concentration. At an annual or seasonal level, variances may occur, depending on the fertilisation, etc. However, it is impossible to link these to the amount of precipitation.

INTERMEZZO III: Calculation examples

At 1m surface level is a drainage system that discharges directly into the drainage system under consideration. The average nitrate concentration in the ground moisture is expected to be higher than in the discharged precipitation. Certainly in case of fertilised surfaces with higher concentration in the toplayer, this is the case. In the examples below, a uniform concentration distribution is the point of departure. In this assumption, the leaching of nutrients is equal to the ratio between the amounts of soil moisture and effective precipitation. Runoff of precipitation occurs if the field capacity is reached. Two examples have been worked out, one for sand with a slight field capacity and one for clay with a large field capacity. Drainage takes place at a depth of 1m and the annual effective precipitation is assumed to be 300 mm/y. As maximum supply of precipitation the infiltration capacity of the type of soil is taken. The precipitation is, however, seldom so heavy that this capacity is reached.

Overview of the degree of thinning of the soil moisture

	Field capacity (m³ soil moisture/m³)	Infiltration capacity (mm/h)	Maximum thinning of the ground water moisture per hour	Average annual thinning of the ground water moisture
Sand	0.2	12	6%	150%
Clay	0.37-0.45	4	0.8-1%	80%

The thinning on a hourly basis is relatively slight. The concentration course as a result of thinning is, therefore, negligibly small.

In case of fertilised surfaces, an increased concentration in the drained ground water may occur, due to migration of nitrate-rich water from the fertilised toplayer of the soil. The interface between nitrate-rich and nitrate-poor ground water is moving in a vertical direction, until it arrives at the drain pipes. NITSOL calculations (Hopstaken et al., 1987) for sandy soils indicate that nitrate concentrations at a depth of 50-75 cm are relatively constant, in case of a step size of decades. Variances in concentration occur mainly in the topmost 25 cm of the soil. In case of smaller step sizes, for example of hours, the concentration course may be very different. As far as known, on-line measuring has never been carried out regarding surface runoff, for example after a fertilisation period. As a result of lack of information, it is proposed to keep the ammonium and nitrate concentrations constant. This however reduces the accurateness of the model results in case of smaller step sizes.

The relation between the ground water level and the denitrification has been investigated (Steenvoorden, 1983, Bouwmans et al., 1989). The ground water level is classified in ground water steps, which are determined by the average highest and average lowest ground water level (GHG or GLG). The denitrification factor indicates with which factor the leaching of nitrate must be corrected. A situation with very low ground water levels (GtVII*) is taken as a reference. These values are, however, applicable to the total nitrate run off, so that translation for the subflows is difficult.

The nitrate concentration in the quick ground water discharge may be linked to the concentration in the deeper soil layers (slow ground water runoff) by means of denitrification factors.

$$S_{NH4-N,quick,t} = Q_{quick,t} * C_{NH4-N,quick,t} \qquad (20\text{-}a)$$

$$S_{NO3-N,quick,t} = Q_{quick,t} * C_{NO3-N,slow,t} / N \qquad (20\text{-}b)$$

Input	$Q_{quick,t}$	[m³/s]	Quick component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{NH4-N,quick,t}$	[mgN/l]	Ammonium-N concentration quick component ground water discharge unpaved surface
	$C_{NO3-N,quick,t}$	[mg N/l]	Nitrate concentration slow component ground water discharge unpaved surface
	N	[-]	Denitrification factor
Output	$S_{NH4-N,quick,t}$	[g N/s]	Ammonium load quick component ground water discharge unpaved surface
	$S_{NO3-N,quick,t}$	[g N/s]	Nitrate load quick component ground water discharge unpaved surface

Phosphor
Significant leaching of phosphor may occur when the ground water level rises into the phosphor saturated zone. In general, also the phosphor fixation capacity in the shallow ground layers in The Netherlands is only partly used. The Ministry of VROM indicated a number of areas in The Netherlands, which are sensitive to P leaching. In the remaining areas, the points of departure will be that the phosphor fixation capacity has not been used in this way, an equilibrium exists between the P-complex and solved P, and phosphor does not leach substantially. Areas with a utilisation degree of the phosphor fixation capacity of over 25% are considered phosphor saturated grounds. In these grounds increased P loads may be leached. The relation between P content in the quick component of ground water discharge and the use degree of the phosphor fixation capacity is a point for further investigation.

The P concentrations are not expected to depend strongly on the precipitation flow rate, but do depend on the adsorption/desorption equilibrium. The P load in the soil is in those cases so large that thinning does not play any meaningful part. Also to phosphor a first order equation is applicable. In addition, phosphor may leach, in the form of fine, suspended matter.

$$S_{P-total,quick,t} = Q_{quick,t} * C_{P-total,quick,t} \qquad (21)$$

Input	$Q_{quick,t}$	[m³/s]	Quick component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{P-total,quick,t}$	[mg P/l]	Phosphor concentration quick component ground water discharge unpaved surface
Output	$S_{P-total,quick,t}$	[g P/s]	Phosphor load quick component ground water discharge unpaved surface

Target values surface runoff, slow and quick component of the ground water discharge
The concentration of surface runoff, the slow and quick component of the ground water discharge of unpaved surface depend mainly on soil type and land use. Three soil types are distinguished:
- sand
- clay
- peat
The next types of land use are distinguished:
- unfertilised land
- fertilised grassland
- fertilised green maize farmland
- fertilised other farmland
Besides these categories, areas with specific land use can be distinguished such as horticulture or bulb farming. The impact of these types of land use in leaching of nutrients is very specific, due to the specific conditions with regret to fertilisation and water management.

Table 7 lists the target values for the types of discharge, specified for soil type and land use. These values are rough estimates based on incidental measurements found in the literature. The concentrations of nutrients in discharges fluctuate over seasons, degree of fertilization, organic content etc.. It is strongly emphasized that these target values are incidental and therefore not representative for other areas. It is therefore strongly recommended to use measured values within the area of interest as much as possible.

Table 7: Target values concentration nutrients

target values unpaved surface (mg/l)											
soil type	unfertilised land			fertilised grassland			fertilised green maize farmland			fertilised other farmland		
	NO3	NH4	PO4	NO3	NH4	PO4	NO3	NH4	PO4	NO3	NH4	PO4
surface runoff												
sand			0,1-3,2c	5-9,5a		0,1-3,2c 2-4a			0,1-3,2c			0,1-3,2c
clay						1-3a						
peat						2a						
quick component of the ground water discharge												
sand	2d			4b 5-9,5a			3b			2b		
clay	1d											
peat	2d											
slow component of the ground water discharge												
sand	1,5d 0,03-4,3e 21-39a	0,08-,36e	<0,01e	21-39a 43d			21-39a 80c 113d			21-39a 20d		
clay	0,07-0,7e	3,4-13,1e	1,4-6e	53d						14d		
peat	0,2-0,8e	0,9-3,6e	0,10-0,38e									

a   Meinardi, 1991
b   Drecht, 1986
c   Meinardi en van der Valk, 1989 (vastgesteld voor totaal-stroomgebied)
d   Steenvoorden et al 1993 (bij GWI en GWVII als totaal-N)
e   Bots et al, 1978 (bij ondiep grondwater 2m-maaiveld)

Target values denitrification factor
Table 8 gives an overview of the denitrification factor for the various ground water steps.

Table 8: Overview of the denitrification factors and ground water steps (van Drecht et al., 1991)

Ground water step	GLG (cm-surface level)	GHG (cm-surface level)	Denitrification factor
I	<50	<25	0.04-0.05
II	50-80	>25	0.08-0.1
III	80-120	25-40	0.22-0.31
IV	80-120	40-80	2.00-0.42
V	120-160	<25	0.15-0.5
VI	120-160	40-80	0.22-0.48
VII	160-220	80-140	0.73-0.83
VII*	220-280	140-200	1

2.   Slow component of ground water discharge
Nitrogen
Nitrogen may also be discharged eventually through the deeper soil layers into the water course (see figure 4) by means of infiltration and percolation. The slow component of ground water discharge has a relatively long retention time in the soil. In addition, the ground water acts as a buffer, by means of

which concentration differences are flattened out to a large extent. This picture is confirmed by calculations of the nitrate concentration by means of the programme NITSOL (Hopstaken et al., 1987). At a depth larger than 2 m. low and constant nitrate degrees are measured. This means that a zero order relation will suffice.

Solved nitrogen mainly occurs in the form of nitrate and ammonium. Ammonium may be nitrificated into nitrate by bacteria in aerobic circumstances. This is denitrified into N_2 in anoxic circumstances (see intermezzo 1). In most cases, the denitrification is the velocity determining step in this reaction chain. Only in case of peaty soil with a high organical fraction (carbon source for denitrificating bacteria) and anaerobic conditions in the ground water (no nitrification) the reverse is the case. In view of the long retention time of the water in the ground, there is a stationary situation. This results in zero order relations for the flow rate of the effective precipitation.

$$S_{NH4-N,slow,t} = Q_{slow,t} * C_{NH4-N,slow,t} \tag{22-a}$$

$$S_{NO3-N,slow,t} = Q_{slow,t} * C_{NO3-N,slow,t} \tag{22-b}$$

Input	$Q_{slow,t}$	[m³/s]	Slow component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{NH4-N,slow,t}$	[mg N/l]	Ammonium-N concentration slow component ground water discharge unpaved surface
	$C_{NO3-N,slow,t}$	[mg N/l]	Nitrate concentration slow component ground water discharge unpaved surface
Output	$S_{NH4-N,slow,t}$	[g N/s]	Ammonium load slow component ground water discharge unpaved surface
	$S_{NO3-N,slow,t}$	[g N/s]	Nitrate load slow component ground water discharge unpaved surface

Phosphor
In section 2.1.2.2 Reaction processes in the soil it is indicated that the adsorption/desorption of soil components is the most important process in the P management. Phosphor is fixed in the soil, because of which a steep phosphor profile comes into existence, which decreases along with increasing depth (Kroese et al, 1990). In The Netherlands the phosphor fixation capacity of the deeper soil layers is still hardly used. The phosphor runoff with deep ground water is, therefore, zero and in any case constant with the time.

$$S_{P-total,slow,t} = Q_{slow,t} * C_{P-total,slow,t} \tag{23}$$

Input	$Q_{slow,t}$	[m³/s]	Slow component ground water discharge unpaved surface (formula 16 or 17)
Model Parameters	$C_{P-total,slow,t}$	[mg P/l]	Phosphor concentration slow component ground water discharge unpaved surface
Output	$S_{P-total,slow,t}$	[g P/s]	Phosphor load slow component ground water discharge unpaved surface

Target values
The concentrations of the slow component of ground water discharge are mainly determined by the type of soil and the land use. Sandy soil, clay soil and peaty soil are distinguished between. A further distinction is made by:
• Non-fertilised land;

- Fertilised grassland;
- Fertilised green maize farmland;
- Fertilised other farmland.

In addition, there are areas with a specific ground use, such as bulb-growing and greenhouse culture. The contribution by these areas to leaching of N and P is very specific due to the specific fertilisation and water management. In this case the user him/herself will have to estimate the parameters or derive these from measuring.

Conclusions
In the description of the water quality it was tried to picture the relation between the P and N loads discharged into the drainage system and the hydrograph. Zero order equations seem to be most suitable for a empirical approach in a simple model. In general, this approach is motivated by means of arguments regarding the processes. On-line measuring data of the N and P concentrations in the sub flows considered are hardly known. Model-related data are often applicable to longer periods (decades, seasons and years). A smaller step size in which also the relation is included with the discharge, requires a much more detailed insight into the processes than is available at this moment.

With regard to the target values of the concentration, the problem arises that the available data usually do not apply to the various ground water flows, on which this study is based. Therefore, the available data need to be translated for the subflows in this study. In addition, many data are not known. Also model-related values usually are not applicable directly to the subflows in this study. These values are often calculated in models, but only act as interim values that are not presented in reports. In order to generate values for the subflows, calculations could be executed, for example by means of ANIMO.

The smaller a step's size, the more the inaccuracy of the model results increases, because on this time scale the inaccuracy in the input parameters increases. This only applies to the description of the water quality.

2.3.5 Seepage
In addition to the discharges that are calculated for open water, paved surface and unpaved surface, the user may enter a term seepage, which is defined for the total surface.

$$q_{seep,t} = \frac{\Delta h}{c} \qquad (24\text{-}a)$$

$$Q_{seep,t} = b\, A_{total}\, q_{seep,t} \qquad (24\text{-}b)$$

Input	Δh	[m]	Hydraulic head difference
	c	[day]	Vertical hydraulic resistance
	A_{total}	[ha]	Total surface
Model Parameters	b^*	[-]	Conversion factor units
Output	$Q_{seep,t}$	[m³/s]	Discharge seepage

* The conversion factor is equal to 10000/(24*3600).

The related water quality is determined by a zero order equation.

$$S_{NH4-N,seep,t} = Q_{seep,t} \, {}^* C_{NH4-N,seep,t} \qquad (25\text{-}a)$$

$$S_{NO3-N,seep,t} = Q_{seept,t} \, {}^* C_{NO3-N,seep,t} \qquad (25\text{-}b)$$

Input	$Q_{seep,t}$	[m³/s]	Discharge seepage (formula 24)
Model Parameters	$C_{NH4-N,seep,t}$	[mg N/l]	Ammonium N-concentration discharge seepage
	$C_{NO3-N,seep,t}$	[mg N/l]	Nitrate concentration discharge seepage

Output	$S_{NH4-N,t}$	[g N/s]	Ammonium load discharge seepage
	$S_{NO3-N,t}$	[g N/s]	Nitrate load discharge seepage

$$S_{P-total,seep,t} = Q_{seep,t} * C_{P-total,seep,t} \tag{26}$$

Input	$Q_{seep,t}$	[m³/s]	Discharge seepage
Model Parameters	$C_{P-total,seep,t}$	[mg P/l]	Phosphor concentration discharge seepage
Output	$S_{P-total,seep,t}$	[g P/s]	Phosphor load discharge seepage

Target values
The values for the seepage and the concentrations depend strongly on the local situation. It is therefore impossible to give target values. Mostly, local data are available about the seepage and the concentrations.

2.3.6 Total discharge and total load

$$Q_{unpaved,t} = Q_{sur,t} + Q_{quick,t} + Q_{slow,t} \tag{27-a}$$

$$Q_{total,t} = Q_{open\,water,t} + Q_{paved,t} + Q_{unpaved,t} + Q_{seep,t} \tag{27-b}$$

Input	$Q_{open\,water,t}$	[m³/s]	Discharge open water surface (formula 2-b)
	$Q_{unpaved,t}$	[m³/s]	Discharge unpaved surface (formula 27-a)
	$Q_{paved,t}$	[m³/s]	Discharge paved surface (formula 6-c)
	$Q_{sur,t}$	[m³/s]	Surface discharge unpaved surface (formula 15-b)
	$Q_{quick,t}$	[m³/s]	Quick component of ground water discharge unpaved surface (formula 16 or 17)
	$Q_{slow,t}$	[m³/s]	Slow component of ground water discharge unpaved surface (formula 16 or 17)
	$Q_{seep,t}$	[m³/s]	Runoff seepage (formula 24)
Model Parameters	-	-	-
Output	$Q_{total,t}$	[m³/s]	Total discharge

The total of nitrate and ammonium loads in a catchment area is determined in accordance with:

$$S_{NH4-N,unpaved,t} = S_{NH4-N,sur,t} + S_{NH4-N,quick,t} + S_{NH4-N,slow,t} + S_{NH4-N,seep,t} \tag{28-a}$$

$$S_{NO3-N,unpaved,t} = S_{NO3-N,sur,t} + S_{NO3-N,quick,t} + S_{NO3-N,slow,t} + S_{NO3-N,seep,t}$$

(28-b)

$$S_{NH4-N,total,t} = S_{NH4-N,open\,water,t} + S_{NH4-N,paved,t} + S_{NH4-N,unpaved,t}$$ (28-c)

$$S_{NO3-N,total,t} = S_{NO3-N,open\,water,t} + S_{NO3-N,paved,t} + S_{NO3-N,unpaved,t}$$ (28-d)

$$S_{org-N,total,t} = S_{org-N,paved,t} + S_{org-N,sur,t}$$ (28-e)

Input	$S_{NH4-N,open\,water,t}$	[g N/s]	Ammonium load open water surface (formula 3-a)
	$S_{NO3-N,open\,water,t}$	[g N/s]	Nitrate load open water surface (formula 3-b)
	$S_{NH4-N,unpaved,t}$	[g N/s]	Ammonium load unpaved surface (formula 28-a)
	$S_{NO3-N,unpaved,t}$	[g N/s]	Nitrate load unpaved surface (formula 28-b)
	$S_{NH4-N,paved,t}$	[g N/s]	Ammonium load paved surface (formula 7-a)
	$S_{NO3-N,paved,t}$	[g N/s]	Nitrate load paved surface (formula 7-b)
	$S_{NH4-N,sur,t}$	[g N/s]	Ammonium load surface runoff (formula 18-a)
	$S_{NO3-N,sur,t}$	[g N/s]	Nitrate load surface runoff (formula 18-b)
	$S_{NH4-N,quick,t}$	[g N/s]	Ammonium load quick component ground water discharge unpaved surface (formula 20-a)
	$S_{NO3-N,quick,t}$	[g N/s]	Nitrate load quick component ground water discharge unpaved surface (formula 20-b)
	$S_{NH4-N,slow,t}$	[g N/s]	Ammonium load slow component ground water discharge unpaved surface (formula 22-a)
	$S_{NO3-N,slow,t}$	[g N/s]	Nitrate load slow component ground water discharge unpaved surface (formula 22-b)
	$S_{NH4-N,seep,t}$	[g N/s]	Ammonium load wash out seepage (formula 25-a)
	$S_{NO3-N,seep,t}$	[g N/s]	Nitrate load wash out seepage (formula 25-b)
	$S_{org-N,paved,t}$	[g N/s]	Organically fixed nitrogen load paved surface (formula 7-c)
	$S_{org-N,sur,t}$	[g N/s]	Organically fixed nitrogen load surface runoff unpaved surface (formula 18-c)
Model Parameters	-	-	-
Output	$S_{NH4-N,total,t}$	[g N/s]	Total ammonium load
	$S_{NO3-N,total,t}$	[g N/s]	Total nitrate load
	$S_{org-N,total,t}$	[g N/s]	Total organically fixed nitrogen load

In the first version of the precipitation runoff module the term organically fixed nitrogen has not been included.

The total phosphor load is determined in accordance with:

$$S_{P-total,unpaved,t} = S_{P-total,sur,t} + S_{P-total,quick,t} + S_{P-total,slow,t} + S_{P-total,seep,t}$$
(29-A)

$$S_{P-total,total,t} = S_{P-total,open water,t} + S_{P-total,paved,t} + S_{P-total,unpaved,t}$$
(29-B)

Input	$S_{P-total,open water,t}$	[g P/s]	Phosphor load open water surface (formula 4)
	$S_{P-total,unpaved,t}$	[g P/s]	Phosphor load unpaved surface (formula 29-a)
	$S_{P-total,paved,t}$	[g P/s]	Phosphor load paved surface (formula 8)
	$S_{P-total,sur,t}$	[g P/s]	Phosphor load surface runoff (formula 19)
	$S_{P-total,quick,t}$	[g P/s]	Phosphor load quick component ground water discharge unpaved surface (formula 21)
	$S_{P-total,slow,t}$	[g P/s]	Phosphor load slow component ground water discharge unpaved surface (formula 23)
	$S_{P-total,seep,t}$	[g P/s]	Phosphor load discharge seepage (formula 26)
Model Parameters	-	-	-
Output	$S_{P-total,total,t}$	[g P/s]	Total phosphor load

2.3.7 Relation ground water discharge and surface water level

The ground water discharges into the drainage system. The discharge therefore depends on the surface water level. This relation can only be included when the surface water level is input from the flow model. This is contrary to the point of departure of a stand alone precipitation runoff module.

Two options are mentioned in order to include this relation without skipping the point of departure of a stand alone precipitation runoff module:

1. simplified calculation of the surface water level
    The surface water level is calculated in the precipitation runoff module by a water balance for the drainage system. The inflow is the calculated ground water discharge, the outflow is the drainage as calculated in a simplified manner. Disadvantage of this option is the separated calculation of the surface water level from the flow model. Because of the simplified calculation in the precipitation runoff module, the calculated surface water level will deviate from the calculated one in the flow model.

2. surface water level as input
    In this option the surface water level is input in the precipitation runoff module. This time series can be obtained from a flow model. By an iterative process, the relation ground water discharge and surface water level can be approached.

The ground water discharge is described by a configuration of linear reservoirs (see section 2.3.4.3). The relation between the ground water discharge and surface water level is implicitly discounted in the time constant of the reservoirs, whereas a constant surface water level is assumed. The relation

between the ground water discharge and surface water level becomes relevant in case of more fluctuating surface water levels.

The fluctuations in surface water levels will be relatively small compared to the fluctuations of the ground water level for sloping areas. Assuming a constant surface water level will be sufficient. However, in specific situation strong fluctuations can occur. For example with large percentages of paved area, so the precipitation will be stored rather quickly in the surface water. Also within downstream polder areas, large decreases of the surface water level can occur.

2.4 Evaluation

With the precipitation runoff module, a model is developed to simulate the discharge processes, both the hydrographs, leaching and runoff of nutrients.

The point of departure of the precipitation runoff module were a simple set-up for operational use, connection with widely used precipitation runoff models, and creating a direct joining of a precipitation runoff module and a flow model. The technical design fits to all point of departure. The simple set-up of the technical design create a widely usable application. Using the soil moisture reservoir and linear reservoirs, the set-up connects to widely used precipitation runoff models. By joining the STOWA/Unie stekkerdoos WATER, a direct joint is made between precipitation runoff module and a flow model.

The set-up chosen is indeed simple but it is also extensive. The user will have to enter a vast amount of parameters before using the module. That this relatively extensive form was chosen anyway is caused by two aspects. On the one hand, the wish existed to make the model suitable for an extensive application area (with regard to type and application). On the other hand, the wish existed to describe both the water quantity and the water quality.

In the precipitation runoff module, pragmatic solutions were often chosen. At some points, the processes are not described (capillary rise, feedback with the surface water level). Depending on the wishes of the users, extensions may be added in a later stage.

2.4.1 Hydrograph description

The Precipitation Runoff Module developed is of a strongly empirical nature. As a result, the parameters in the model usually do not have a direct physical meaning. Therefore, target values for the model parameters have been included in this manual. In view of the complexity of the processes in catchment areas (local variation in type of soil, slope, ground use, etc.), also the target values indicated will cause deviations in the results. *It is strongly recommended to calibrate the model parameters based on measured discharges.*

2.4.2 Description water quality

In the theory it was concluded that the processes of leaching and runoff of nutrients are extremely complex. The value of a simple concept for the description of the water quality will therefore be restricted. Since an estimate based on fist rules and target values obtained from literature will give a best guess, this concept will be helpfull for water boards. Also due to the complexity of the processes of micro pollutants, a description of these solutes was excluded from RAM. RAM is therefore restricted to the leaching and runoff of nutrients only.

Point of departure for the description of the water quality is a direct link with the hygrograph. Concentrations are attributed to the subflows, which are affected by the supply, the reaction processes and the discharge. These concentrations are worked out for nitrogen, phosphor and ammonium. The experience with this concept can be used to
decide whether a more detailed concept is necessary or not.

Similar to the hydrograph description, it is strongly recommended to calibrate the model parameters.

2.4.3 Recommendations

After delivery of the first version of the precipitation runoff module, experience will be acquired in using the module. Based on these experiences and supplementary wishes, the precipitation runoff module may be extended in a later stage.

Aspects that were addressed during the development process of the precipitation runoff module, may increase the applicability of the precipitation runoff module. Some relevant points of improvement are described below.

Ground water discharge reduction in case of high surface water levels
In case of high surface water levels, the ground water runoff may stagnate. In the current version of the precipitation runoff module the user him/herself needs to determine when reduction occurs. The applicability of the precipitation runoff module will increase, if the ground water runoff is dependent from the surface water level (see section 3.7).

Refinement soil moisture reservoir
In the current version of the precipitation runoff module linear relations may be entered for the evapotranspiration relation (formula 12) and the percolation relation (formula 13). The applicability of the soil moisture reservoir is increased, if the user her/himself is able to define a (non-linear) relation. Furthermore, the soil moisture reservoir may be improved by including a capillary rise relation and by adding a retardation term.

Determination maximum percolation and distribution code
In the soil moisture reservoir the maximum percolation is entered by the user (formula 13-c). Hardly any guidelines for these values are known in the literature. In a more extensive version, the determination of the maximum percolation may be worked out in further detail. This also applies to the distribution code for the slow and quick ground water runoff (formulas 16 and 17).

Water quality description
The usability of the water quality description in the precipitation runoff module will have to be monitored critically. It is recommended that the model is tested during a prolonged period of time in which the model results are compared to the measuring values (calibration). From an evaluation of these experiences, it will appear whether the differentiation within the subflows is sufficient, or that a further differentiation is deemed useful. Based on this evaluation the model may be adapted.

3. Getting Started

3.1 Define a Project

After you have started the program you can define a new project by choosing the New commando in the File menu. RAM will display the New Project dialog box. For configuring a project RAM needs a number of input files. These include:

- node file
  This file contains the nodes of the scheme.
- network file
  This file contains the network - the relations of the nodes - of the scheme.

The Node and Network file cannot be generated by RAM. They are simply ASCII files which can be made with a simple editor. They follow the File descriptions of DUFLOW. Refer to the chapter on File Formats (page 88) for more information. The setup program did install a demo Node and Network File (MARKMOD.NOD and MARKMOD.NET). Please enter these filenames, including their complete path, in the New Project dialog box as shown below.
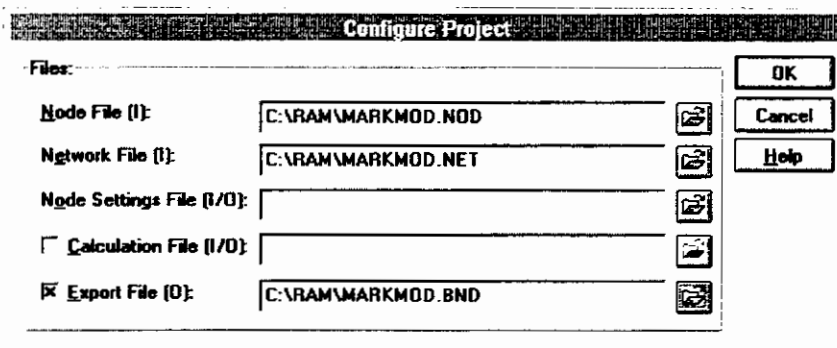
You can also use the File Open dialog box by pressing the ![icon] button.

In fact your new project has now been defined but because we want to use the calculation results in another program we check the **Export File (O)** checkbox and enter the pathname of the export file. During its calculation RAM will generate a DUFLOW compatible result file.

Press **OK** and RAM will display a RAM project window consisting of two panes. The left pane shows the network (retrieved from the Network and Node Files), the right pane will show data graphs which we will see later on.

3.2 Configure the Precipitation and Evaporation

RAM needs a lot of input for its calculations. Among them are the precipitation and the evaporation. To enter this data please follow these step by step instructions:

- Choose the Precipitation command in the File Menu. RAM will show you the Precipitation dialog box.

- Press the **Insert After** button. RAM will insert the line

  `00:00:00        0.000`

- Repeat this 9 times

- Select the first line in the listbox. RAM will jump automatically to the **Value** editfield.

- Enter 2.5 and press the <RETURN> key. RAM will automatically select the next line in the listbox and jump again to the **Value** editfield.

- Use the same approch to enter the numbers

  1

  0.5

  3

  5

  2

  0

  3.5

  4

  1

- Because we want to start our calculation in januari 1996 instead of 1995 we will shift the time series. Select all the lines in the listbox and choose the **Shift** button. RAM will display the Shift values dialog box.

- Check the **Forward in Time** radiobutton

- Enter 365 in the **Days** editfield.

- Press the **OK** button. You will notice RAM has shifted the time series to 1996.

- Press **OK** (in the Precipitation dialog box)

- RAM will display the Precipitation graph in its right pane

Repeat these steps for entering the Evaporation but make the following modifications:

- Enter 3 lines with the values 1, 0.2 and 0.8.
- Change the **Date** and **Time** edit fields to

  01-01-1996 00:00:00

  04-01-1996 00:00:00

  10-01-1996 00:00:00

  [Since RAM tries to maintain its data integrity you are forced to start changing these date values backwards]

3.3 Configure the Nodes

In order to calculate the runoff and the loads of the nodes in the network RAM needs to know a lot of properties of these nodes. To enter this properties please follow these steps:

- Choose the Properties command in the File - Nodes menu. RAM will show you the Node Properties dialog box.

  Since RAM needs such a lot of data RAM will allow you to simultaneously enter data for a number of nodes. In the **Nodes to Change** combobox you can choose to change:

  All nodes

  Checked nodes (only available when nodes are checked)

  individual nodes

- Select the line 1 0 0 in the **Nodes to Change** combobox.

  The amount of data per node is split in to logical categories. You can select the following categories in the categories listbox:

  Area

  Q (open surface)

  Q (paved surface)

  Q (unpaved surface)

 Q (seepage)

  Ammonium

  Nitrate

  Phosphor

  Please refer to the chapter Background (page 2) for a detailed description of the data.

- Select Q (unpaved surface) in the Categories listbox. RAM will display at the right side of the dialog the unpaved surface settings. Because the unpaved surface settings are rather extensive and because they depend much on the type of surface of the node RAM works with schemes. This enables you to simply reuse the unpaved surface settings for other nodes.
- Choose the ... button at the right side of the dialog box. RAM will display Select Unpaved Surface Scheme dialog box. Since there are no schemes available we can only add a new one.
- Choose the **Add** button. RAM will display the Unpaved Surface Settings dialog box.
- Enter *sand* in the **Surface Type** editfield.
- Enter the desired values for the unpaved surface in the dialog.
- Press the **OK** button.

- Press the **OK** button in the Select Unpaved Surface Scheme dialog box. RAM will show the values of the unpaved surface scheme in the Node Properties dialog box.
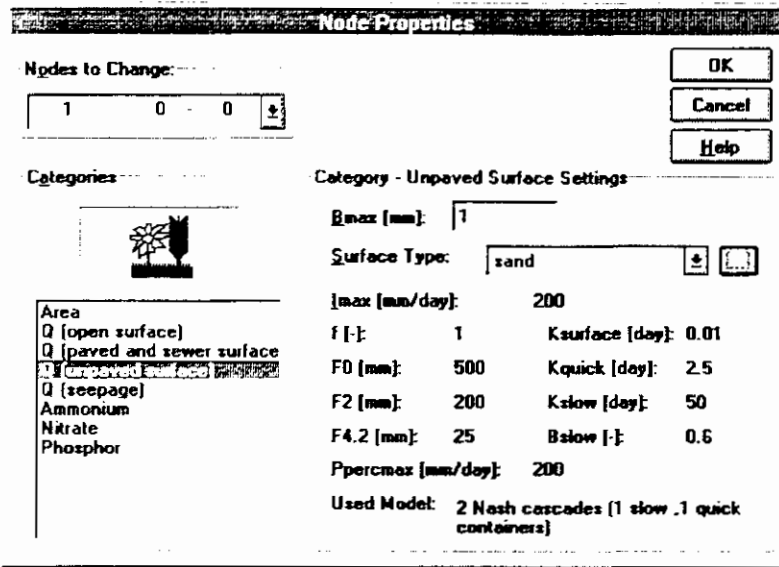

You can enter data for the other categories following the same strategy. In case of Ammonium, Nitrate and Phosphor RAM also uses schemes. These schemes are in fact time series and can be entered using dialog boxes with the same appearance as the Precipitation and Evaporation dialog box.

3.4 Configure and Start the Calculation

Finally RAM needs to know for what period you want to calculate the results. You can specify these settings as follows:

- Choose the Model Calculation Settings command in the Options menu. RAM will display the Model Calculation Settings dialog box.
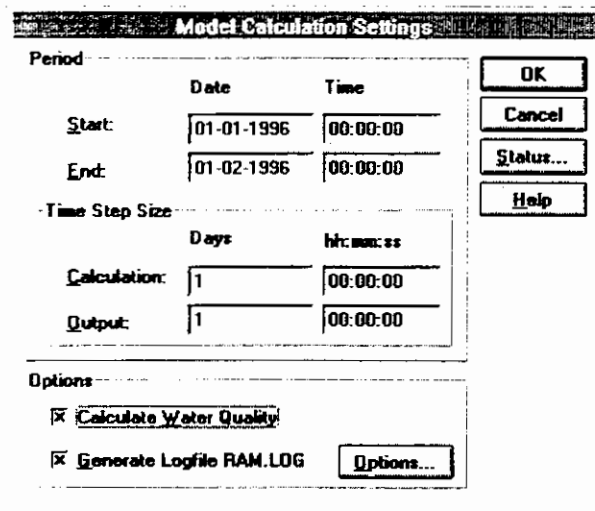
- Enter 01-01-1996 in the **Start Date** edit field
- Enter 01-02-1996 in the **End Date** edit field
- Check the **Calculate Water Quality** checkbox
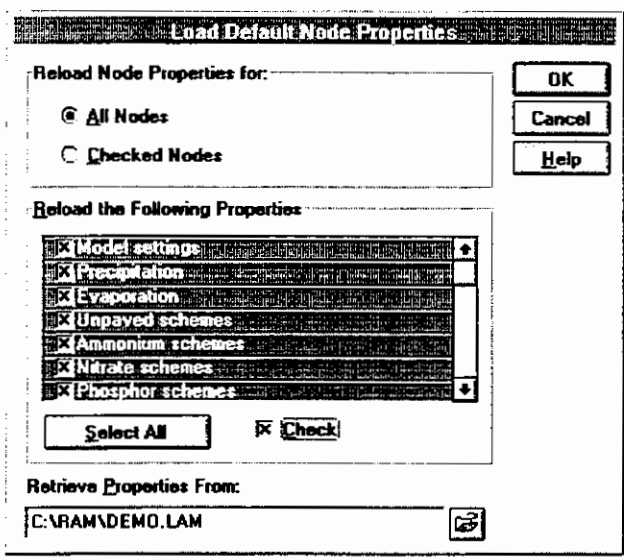- Press the **OK** button

RAM is now ready to calculate the results.

- Choose the Update Calculation command from the Model menu. Unfortunately RAM will display an extensive error report because it needs more data.
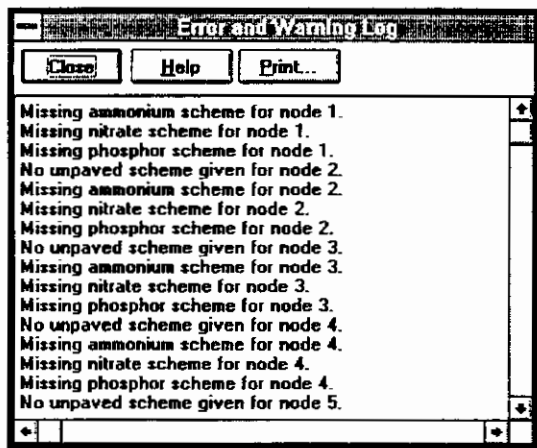
You could enter all the required data manually as you have learned in the previous paragraphs but this is to much work in this introduction. It is now time to cheat and use another powerfull feature of RAM. RAM is able to reload settings from an old Node Settings File. Please follow these steps:

- Choose the Load Defaults command from the Edit - Nodes menu. RAM will show the Load Default Node Properties dialog box.

- Press the **Select All** button

- Check the **Check** checkbox.

- Press the button and select the file DEMO.LAM file in the Select Properties From dialog box (this file is installed by the RAM setup program)

- Press the **OK** button.

[N.B. By reloading settings from a file RAM will overwrite the corresponding settings of the current project.]

- Choose the Update Calculation command from the Model menu to restart the calculation. RAM will display a Calculation Progress dialog box.


Calculating node 7, paved surface (4000 of 12961).

Cancel
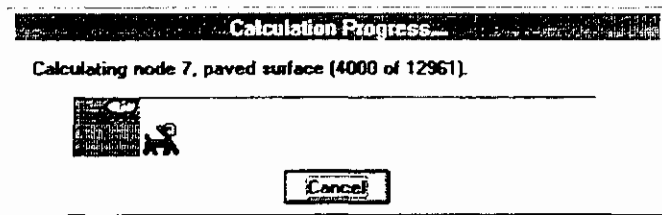
3.5 Display the Results

After succesfully completing the calculations we are now able to display the results in the right pane of the project window. In this pane you can only show runoff and load graphs of checked nodes. Suppose you want to check node 1. You can check this node as follows:

- Make sure RAM is in zoom mode; in the Edit menu there is a checkmark before the option Zooming Tool and the zoombutton in the toolbar is pressed:
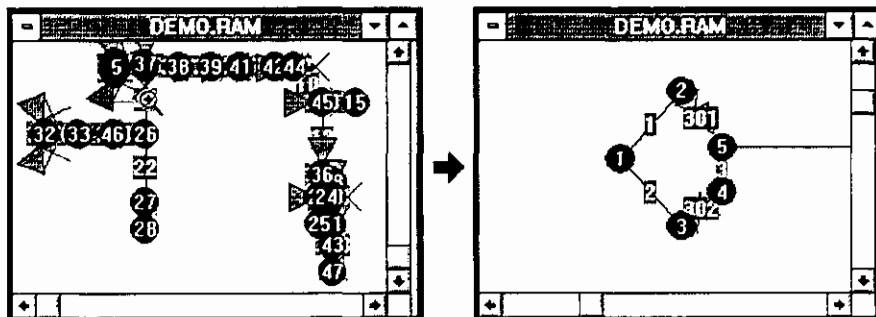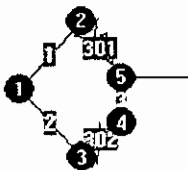

selection mode :
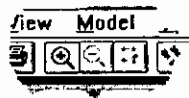
zoom mode:

- Position the mouse near node 1 (hidden behind node 5), press the left mouse button and drag it. Make sure node 1 is in the rectangle which RAM draws while dragging and release the mouse button.
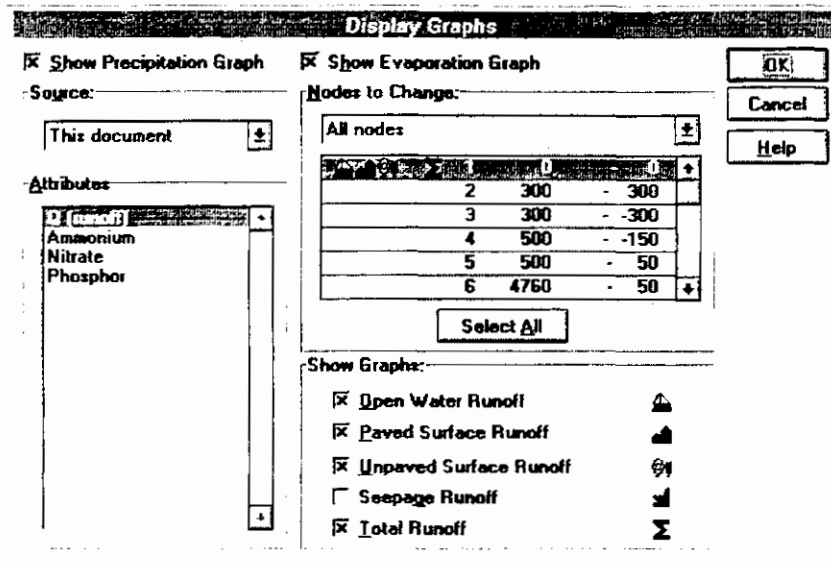

Repeat this process if necesary.

- Change RAM to Selection mode via the buttonbar or the Edit menu.

- Click node 1; it will be displayed in the selection color.

[You can also check nodes in the Check Nodes dialog]

When node 1 is selected you can display its graphs.

- Choose the Display Graphs command in the View menu. RAM will display the Display Graphs dialog box.


- Check the **Show Precipitation Graph** and **Show Evaporation Graph** checkboxes if you want to see these graphs.

- Check the **Open Water Runoff, Paved Surface Runoff , Unpaved Surface Runoff** and **Total Runoff** checkboxes for node 1. You can also click directly in the listbox.

  [RAM also offers the possibility to display results from other files (DUFLOW compatible files and RAM calculation files). If you have loaded such a file, via the Import Reference Data dialog box you can choose them as source in the **Source** groupbox.]

- Press the **OK** button

RAM will display the graphs.
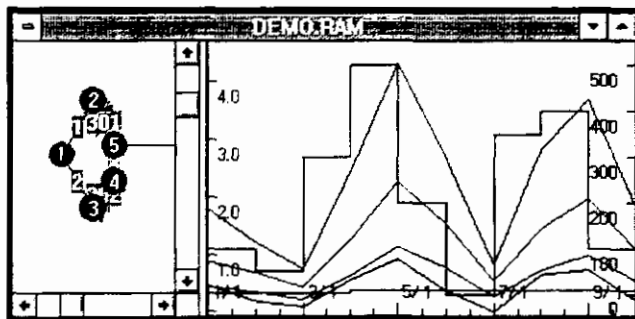
3.6 Tips

Use the Help funtions

The help functions of RAM can be invoked in several ways.

using the Help menu	Get general RAM help or general Windows help.
F1 key	Help about the active window or dialog will be displayed.
using the Help button in dialogs	Displays help about the active dialog. Has the same effect as using the F1 key.

using the context help commando:

The cursor changes to an arrow and question mark. Help about the subsequently clicked object will be displayed.

[?]

in the buttonbar

using the SHIFT-F1 key   same as for the context help button.

Tips for buttons and menu

RAM gives a description of menu options using the statusbar at the bottom of the window. For both menu and buttonbar RAM will show the description if you press the mouse (or keyboard for the menu) above the options. If you release the mouse outside the option the option will be canceled.

RAM also gives tips by yellow balloons above the toolbar. Locate the mouse above the button, don't press the mouse button, and in a few seconds a balloon is displayed.
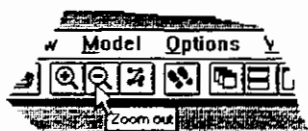
Using the right menu

In order to speed up operations for experienced users RAM supports the right mouse button in the Network window as wel as in the Graph window. When you press the right mouse button RAM displays a context menu containing the most frequently used commands.

Zooming and Selection mode

RAM supports two modi for the Network window. Since it is most likely for you to change these modes frequently RAM enables you to zoom while staying in Selection mode.
In Selection mode the following extensions are supported:

SHIFT key	the nodes in the dragged rectangle will be added to the already checked nodes.
CTRL key	the check status of the nodes in the dragged rectangle will be toggled.
SHIFT+CTRL key	RAM will zoom in to the dragged rectangle. The check status of the nodes will not be altered.

Speed up calculation

It is possible to speed up calculation by only setting the options you really need:

- If you are interested in only a few nodes set the **Total Area** in the Node Properties dialog box to 0 for the other nodes.
- Use the log options sparingly; only checked nodes.
- Calculate loads only if you need them.
- Choose the time steps as large as possible.

Making a backup of your project files.

Please also refer to chapter 7 File Formats. If you plan to make a backup of your project data files be sure also to backup at least the following files:

file	description	when
*.RAM	RAM configuration file	always
*.LAM	Node Settings file	always
*.DAT	**index file of the Node Settings file.**	**always**
*.NOD	nodes file	optionally
*.NET	network file	optionally

4. Commands

4.1 File menu commands

The File menu offers the following commands:

New	Creates a new set of input- and output-files (a new Project).
Open	Opens an existing Project File.
Configure Project	Redefines the set of input- and output-files (the Project or the Project File).
Close	Closes an opened Project.
Save	Saves a Project File using the same file name.
Save As	Saves a Project File to a specified file name.
Print	Prints the contents of the active project.
Print Preview	Displays the project contents on the screen as it would appear printed.
Print Setup	Selects a printer and printer connection.
Page Setup	Defines the relative size of the graph, and the printed line styles
1, 2, 3, 4	Opens the most recently opened projects
Exit	Exits RAM.

4.1.1 New command

Use this command to create a new Project in RAM. Select the files that you want to use in the File New dialog box.

You can open an existing Project File with the Open command.

Shortcuts

Toolbar: ⬜
Keys: CTRL+N

4.1.2 Open command

Use this command to open an existing project file in a new window. Select the (type of) file in the File open Dialog Box You can open multiple projects. Use the Window menu to switch among the multiple open projects. See Window 1, 2, ... command.

You can create a new project with the New command.

Shortcuts

Toolbar: ⬜
Keys: CTRL+O

4.1.3 Configure command

Use this command to redefine the Project in the Configure Project dialog box.

4.1.4 Close command

Use this command to close the project window. RAM suggests that you save changes to your files before you close the project. If you close a project without saving, you lose all changes made since the last time you saved it. Before closing an untitled project, RAM displays the Save As dialog box and suggests that you name and save the *.RAM and *.LAM-files.

You can also close a project window by using the Close icon on the document's window, as shown below:

4.1.5 Save command

Use this command to save the Project(*.RAM)- and Node Settings(*.LAM)-files to its current names and directories. When you save a file for the first time, RAM displays the Save As dialog box so you can name your files. If you want to change the name and directory of an existing file before you save it, choose the Save As command.

Shortcuts

Toolbar: ■

Keys: CTRL+S

4.1.6 Save As command

Use this command to save and name the active Project (*.RAM) file. RAM displays the Save As dialog box so you can name your files.

To save files with their existing names and directories, use the Save command.

4.1.7 Print command

Use this command to print a document. This command presents a Print dialog box, where you may specify the range of pages to be printed, the number of copies, the destination printer, and other printer setup options.

Shortcuts

Toolbar: 🖨

Keys: CTRL+P

4.1.8 Print Preview command

Use this command to display the active document as it would appear when printed. When you choose this command, the main window will be replaced with a print preview window in which one or two pages will be displayed in their printed format.

The print preview toolbar offers you options to view either one or two pages at a time; move back and forth through the document; zoom in and out of pages; and initiate a print job.

4.1.9 Print Setup command

Use this command to select a printer and a printer connection. This command presents a Print Setup dialog box, where you specify the printer and its connection.

4.1.10 Page Setup command

Use this command to change the layout of the printed pages. RAM presents the Page Setup dialog box.

4.1.11 2, 3, 4 command

Use the numbers and filenames listed at the bottom of the File menu to open the last four Projects you closed. Choose the number that corresponds with the Project you want to open.

4.1.12 Exit command

Use this command to end your RAM session. You can also use the Close command on the application Control menu. RAM prompts you to save projects with unsaved changes.

Shortcuts
Mouse: Double-click the application's Control menu button.

Keys: ALT+F4

4.2 Edit menu commands

The Edit menu offers the following commands:

Zooming tool		Zooms in on the network
Zoom out		Zooms out to the previous stage of zooming
Entire network 100%		Shows the entire network
Nodes	Properties	Sets all node properties
	Check	Checks the nodes
	Load Default	Loads default node settings, per node, from file
Precipitation		Edits precipitation parameters
Evaporation		Edits evaporation parameters

4.2.1 Zooming tool command

Use the zooming tool to show parts of the network in more detail. After selecting the command (from the menu or the toolbar) the cursor will change into a magnifying glass. Dragging the cursor displays a rectangle on your screen. This rectangle represents the area that will be magnified (the rectangle will be blown up until it fills the network window).

To end the zooming deselect the menu-item or the toolbar button.

Shortcuts

Toolbar:

4.2.2 Zoom out command

Zooming is usually done in stages, more and more detail of the network is displayed. Zooming out lets you retrace these stages. Zoom out works independent from the zooming tool (the zooming tool needn't be selected to zoom out).

To zoom out to the unzoomed state use the Entire network command

Shortcuts

Toolbar:　　⊕

4.2.3 Entire network command

The entire network command shows the entire network (before zooming). instead of zooming out in stages (Zoom out command).

Shortcuts

Toolbar:　　⅔

4.2.4 Properties command

Use this command to edit node properties. After selecting the command RAM displays the Node Properties dialog box.

4.2.5 Check command

Use this command to check nodes. The selection is made in the Check Nodes dialog box.

Checked nodes are used to display graphs, in the Node Properties and Load defaults dialog boxes and for generating the logfile.

Nodes can also be checked with mouse actions (see Network Window).

4.2.6 Load Defaults command

Use this command to load defaults, from Node Settings files, for properties. RAM shows the Load Default Node Properties dialog box in which the property and file selection is made.

4.2.7 Precipitation command

Use this command to set or modify the Precipitation time series. RAM shows the Precipitation dialog box.

4.2.8 Evaporation command

Use this command to set or modify the Evaporation time series. RAM shows the Evaporation dialog box.

4.3 View menu commands

The View menu offers the following commands:

Toolbar	Shows or hides the toolbar.
Status Bar	Shows or hides the status bar.
Legend	Shows or hides the Legend Window
Display Graphs	Sets display options per node

4.3.1 Toolbar command

Use this command to display or hide the Toolbar, which includes buttons for some of the most common commands in RAM, such as File Open. A check mark appears next to the menu item when the Toolbar is displayed.

See Toolbar (page 84) for help on using the toolbar.

4.3.2 Status Bar command

Use this command to display or hide the Status Bar, which describes the action to be executed by the selected menu item or depressed toolbar button, and keyboard latch state. A check mark appears next to the menu item when the Status Bar is displayed.

See Statusbar (page 85) for help on using the status bar.

4.3.3 Legend command

Use this command to display or hide the Legend window, which describes the contents of the Graph window.

4.3.4 Display Graphs command

Use this command to set display options per node, and per source and for precipitation and evaporation. After selecting the command RAM shows the Display Graphs dialog box.

4.4 Model menu commands

4.4.1 Update Calculation

Use this command to update the calculation. RAM will display a calculation Progress dialog box which enables you to cancel the calculation.

4.5 Options menu commands

The Options menu offers the following commands.

Model Calculation Settings	Sets the time settings of the calculation
Colors Graph Window	Configures the colors of the graph window
Styles and Colors Network Window	Configures the colors and styles of the network window
Import Reference Data	Imports external data

4.5.1 Model Calculation Settings command

Use this command to set the settings that govern the calculations. RAM will show the Model Calculation Setting dialog box.

4.5.2 Colors Graph Window command

Use this command to change the colors in the graph window. After the selection of the command RAM will show the Colors Graph Window dialog box.

4.5.3 Styles and Colors Network Window command

Use this command to customize the styles and colors of the nodes, sections and other features in the Network Window. After selecting the Styles and Colors Network Window command RAM will show the Styles and Colors dialog box.

4.5.4 Import Reference Data

Use this command to import data that can be compared to the calculation data generated by RAM. After selecting the command RAM will show the Import Reference Data dialog box.

4.6 Window menu commands

The Window menu offers the following commands, which enable you to arrange multiple project windows in the application window.

Cascade	Arranges windows in an overlapped fashion.
Tile Horizontal	Arranges windows in non-overlapped tiles.
Tile Vertical	Arranges windows in non-overlapped tiles.
Arrange Icons	Arranges icons of minimized windows.
Window 1, 2, ...	Activate the specified window.

4.6.1 Cascade command

Use this command to arrange multiple opened windows in an overlapped fashion.

4.6.2 Tile Horizontal command

Use this command to horizontally arrange multiple opened windows in a non-overlapped fashion.

4.6.3 Tile Vertical command

Use this command to vertically arrange multiple opened windows in a non-overlapped fashion.

4.6.4 Arrange Icons command

Use this command to arrange the icons for minimized windows at the bottom of the main window. If there is an open project window at the bottom of the main window, then some or all of the icons may not be visible because they will be underneath this project window.

4.6.5 2, ... command

RAM displays a list of currently open project windows at the bottom of the Window menu. A check mark appears in front of the project name of the active window. Choose a project from this list to activate its window.

4.7 Help menu commands

The Help menu offers the following commands, which provide you assistance with RAM.

Index	Offers you an index to topics on which you can get help.
Using Help	Provides general instructions on using help.
About	Displays the version number of RAM.

4.7.1 Index command

Use this command to display the opening screen of RAM Help. From the opening screen you can jump to several RAM help topics.

Once you open Help, you can click the Contents button whenever you want to return to the opening screen.

4.7.2 Using Help command

Use this command for instructions about using Help.

4.7.3 About command

Use this command to display the copyright notice and version number of your copy of RAM, in the About RAM dialog box.

4.7.4 Context Help command

Use the Context Help command to obtain help on some portion of RAM. When you choose the Toolbar's Context Help button, the mouse pointer will change to an arrow and question mark. Then click somewhere in the RAM window, for example another Toolbar button. The Help topic will be displayed for the item you clicked.
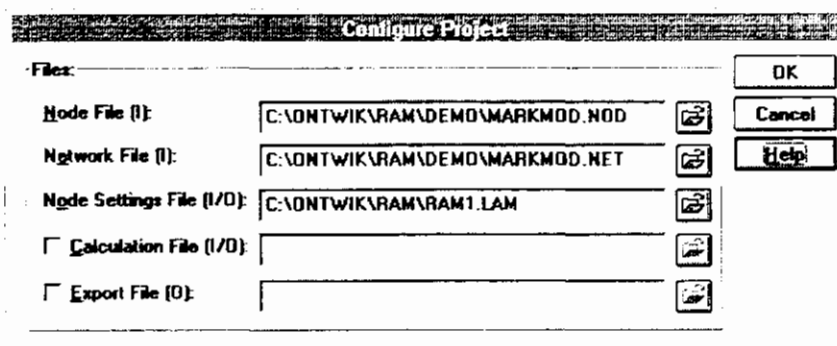
Shortcut

Keys: SHIFT+F1

5. Dialogs

5.1 File menu related

5.1.1 New Project or Configure Project dialog box

Specify the files you wish to use in the RAM-project. All project data (or reference to data in files) can be stored in a Project File after choosing Save in the File menu.
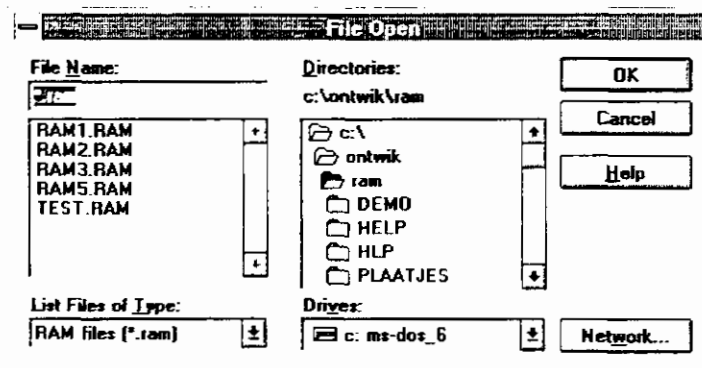
Configure Project		
Files:		OK
Node File (I):	C:\ONTWIK\RAM\DEMO\MARKMOD.NOD	Cancel
Network File (I):	C:\ONTWIK\RAM\DEMO\MARKMOD.NET	Help
Node Settings File (I/O):	C:\ONTWIK\RAM\RAM1.LAM	
☐ **Calculation File (I/O):**		
☐ **Export File (O):**		

The following file-types are feasible:

Node File	input only	*.NOD	File that contains the position of nodes. The nodes are used as calculation points.
Network File	input-only	*.NET	The nodes are connected through a network. The Network File contains the network, and its geographical dispersion.
Node Settings File	input and output	*.LAM	Custom RAM settings are stored in the Node Settings File
Calculation File	input and output (optional)	*.CLC	Calculations can be stored in a Calculation File (to prevent loss of data). This is useful in case of extended calculations.
Export File	output only (optional)	*.BND	The Export File is used as an interface to DUFLOW. The generated data can be used in further calculations in DUFLOW. These files can also be imported via the command Import Reference Data

The file selection can be made after clicking the buttons behind the editfields. The displayed selection dialog is the same as the File Open dialog box.

5.1.2 File Open dialog box

This dialog is used by RAM to open files. Because RAM uses many files you will encounter this dialog box in several places.

The following options allow you to specify which file to open:

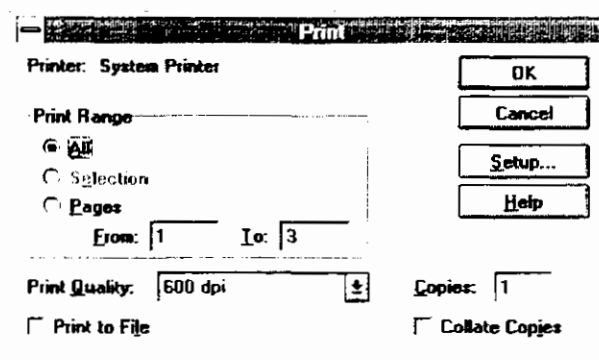|	
File Name	Type or select the file you want to open. This listbox lists files with the extension you select in the **List Files of Type** combobox.
List Files of Type	Select the type of file you want to open (depending on the context): *.CLC is the extension for a calculation file *.BND is the extension for an export file *.LAM is the extension for a RAM node settings file *.NET is the extension for a network file *.NOD is the extension for a node file *.RAM is the extension for a project File
Drives	Select the drive in which RAM locates the file that you want to open.
Directories	Select the directory in which RAM locates the file that you want to open.
Network...	Choose this button to connect to a network location, assigning it a new drive letter.

5.1.3 File Save As dialog box
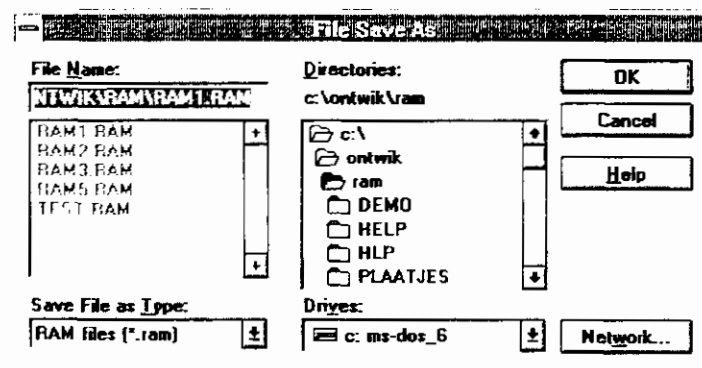
The following options allow you to specify the name and location of the Project File you're about to save.

|	
File Name	Type a new name to save the Project with a different name. A filename can contain up to eight characters and an extension of up to three characters. RAM adds the extension you specify in the Save File As Type box (i.e. *.RAM).
Drives	Select the drive in which you want to store the Project.
Directories	Select the directory in which you want to store the Project.
Network...	Choose this button to connect to a network location, assigning it a new drive letter.

5.1.4 Print dialog box

The following options can be chosen before the printing starts:

|	
Print Range	Specify the pages you want to print:
	All - prints the entire document
	Pages - Prints the pages you specify
Print Quality	Choose the print quality you want
Print to File	Prints to a file on the drive you specify instead of routing it directly to a printer. You store the project print commands in a file so that you can print from another computer (with the same printer driver) that does not have RAM installed. When you choose the OK button, RAM displays a dialog box so that you can type a new filename.
Copies	Type the number of copies you want to print
Collate Copies	Organizes pages when you print multiple copies. RAM prints a complete copy of the first document before it begins to print the first page of the second document.
Printer	Select a printer and a printer connection. You can also control default printer settings for the selected printer. See Print Setup dialog box

5.1.5 Print Setup dialog box

Select a printer and a printer connection. You can also control default printer settings for the selected printer. All options are printer specific.
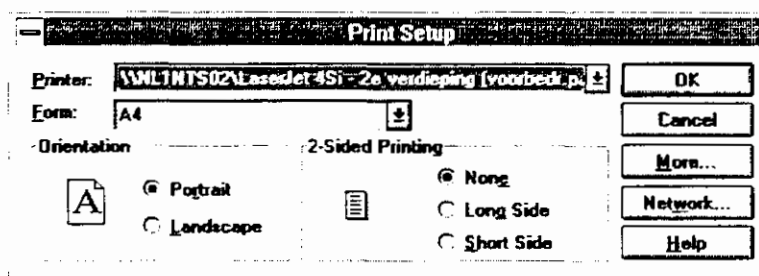
5.1.6 Page Setup dialog box

To fit the graphs and its legend to a page use the Page Setup dialog box. By typing the relative size of the graph, more or less of the legend can be shown on the graph page.
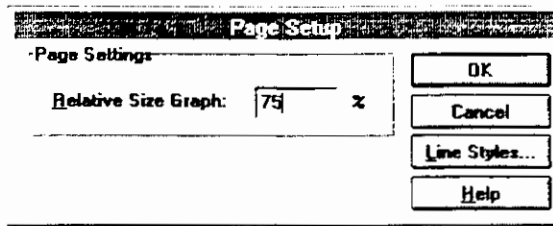

Line Styles can be set in the Line Styles on BW Devices dialog box.

5.1.7 Line Styles Graphs on BW Devices dialog box

All graphs are shown in color on your screen (unless you have a monochrome display adapter). The difference between lines might get lost when printing on a black and white printer. The Lines Styles dialog box substitutes styles for colors. A line style can be chosen for each predefined line.

The settings can be used as default by clicking the checkbox "Use as Default Settings".
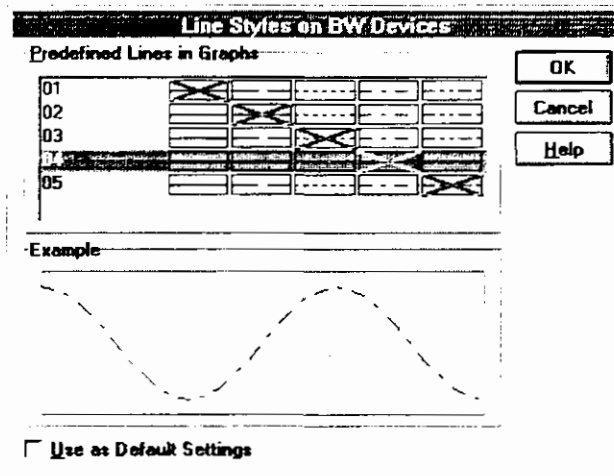
5.2 Edit related dialogs

5.2.1 Node Properties dialog box

Modifying properties of the nodes is done in the Properties dialog box.

First a node selection has to be made using the **Nodes to Change** combo box. The numbers are respectively the node number, the x-coordinate and the y-coordinate of the node. One separate node can be modified, all nodes can be changed at the same time, or the properties of a selection of nodes (see Check Nodes dialog box) can be changed.

```
┌──────────────────────────────────────────────────────────────────┐
│ ▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓ Node Properties ▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓        │
│ ┌─ Nodes to Change: ──────────────┐         ┌──────────┐         │
│ │                                 │         │    OK    │         │
│ │    1        0  ·  0      ±       │         ├──────────┤         │
│ │                                 │         │  Cancel  │         │
│ └─────────────────────────────────┘         ├──────────┤         │
│                                              │   Help   │         │
│ ┌─ Categories ──────┐  ┌─ Category - Unpaved Surface Settings ──┐ │
│ │                   │  │ Bmax [mm]:   1                         │ │
│ │        ❋          │  │ Surface Type:   sand          ±  [...] │ │
│ │                   │  │ Imax [mm/day]:      200               │ │
│ │ Area              │  │ f [-]:        1      Ksurface [day]: 0.01│
│ │ Q (open surface)  │  │ F0 [mm]:    500      Kquick [day]:  2.5 │ │
│ │ Q (paved and sewer surface│ F2 [mm]:    200   Kslow [day]:  50 │ │
│ │ Q (unpaved surface)│ │ F4.2 [mm]:   25      Bslow [-]:    0.6 │ │
│ │ Q (seepage)       │  │ Ppercmax [mm/day]:  200               │ │
│ │ Ammonium          │  │ Used Model:  2 Nash cascades (1 slow ,1 quick│
│ │ Nitrate           │  │              containers)              │ │
│ │ Phosphor          │  └───────────────────────────────────────┘ │
│ └───────────────────┘                                            │
└──────────────────────────────────────────────────────────────────┘
```

The following categories of properties are modifiable, the properties (and the dialog) change when you select a new category:

icon	category	properties	
❋ icon	Area	Total area	Precipitation collection area [ha]
		% Open	Percentage of the total area that consists of surface water [-]
		% Paved	Percentage consisting of (fast spouting) paved surface [-]
		% Unpaved	Percentage of the area used as farmland. (the precipitation is flowing away slowly). [-]
		% Sewer	Sewer, used in the calculations. [-]
△ icon	Open surface	k	Time constant, reservoir separated sewer system [day]
		f	Crop factor Makkink [-]
🏭 icon	Paved surface	ks	Time constant, reservoir separated sewer system [day]
		kp	Time constant reservoir paved surface [day]

Note: For the crop factor Makkink (f) the open surface value is also used for paved surface.

icon	category	properties	
❋ icon	Unpaved surface	Bmax	Maximum storage in surface depressions [mm]
		Surface type	Surface Type and its contents are set in the Select Unpaved Surface Scheme dialog box
◣ icon	Seepage	.. C	vertical hydraulic resistance of covering layer [day]
		DH	hydraulic head difference covering layer and water transporting package [m]

	Ammonium	Concentration schemes for: Open Water Paved Surface Unpaved Surface (Open) Unpaved Surface (Slow) Unpaved Surface (Fast) Seepage

Concentration schemes are selected in the Select Concentration Scheme dialog box

|	Nitrate	Concentration schemes for: Open Water Paved Surface Unpaved Surface (Open) Unpaved Surface (Slow) Unpaved Surface (Fast) Seepage

Concentration schemes are selected in the Select Concentration Scheme dialog box

N   Nitrate concentration

	Phosphor	Concentration schemes for: Open Water Paved Surface Unpaved Surface (Open) Unpaved Surface (Slow) Unpaved Surface (Fast) Seepage

Concentration schemes are selected in the Select Concentration Scheme dialog box

5.2.2 Select Unpaved Surface Scheme dialog box

Properties describing the unpaved surface are grouped in a Unpaved Surface scheme. The schemes facilitate the use of predefined data and the use of schemes from other projects All schemes available are shown in the listbox.
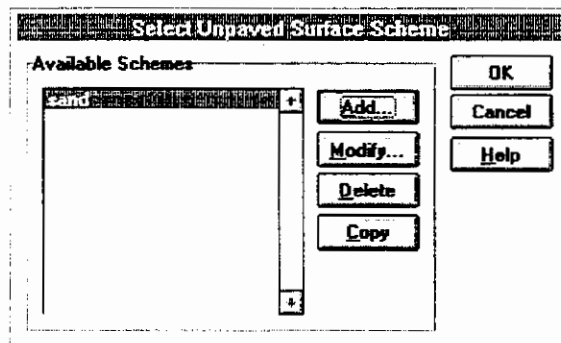
Add, Modify   Schemes can be added or modified by using the appropriate button. **Modify** will show the Unpaved Surface Settings dialog box with the schemes values. **Add** will show the same dialog with the default values.

Delete   Deletes the selected scheme

Copy   Copies the selected scheme in the listbox to make small alterations without changing the original. The copied scheme has the same name and an added number.

5.2.3 Unpaved Surface Settings dialog box

Fill out the unpaved surface scheme, using the following parameters:

Heading	Properties	Explanation
Surface Type		Scheme name
General Attributes	Imax	Infiltration capacity [mm/day]
	f	Cropfactor Makkink [-]
	F0	moisture storage at pF = 0 [mm]
	F2	moisture storage at pF = 2 [mm]
	F4.2	moisture storage at pF = 4.2 [mm]
	Ppercmax	Percolation to saturated zone between pF = 0 en pF = 2 (maximum) [mm/day]
	Ksurface	Time constant reservoir unpaved surface [day]
	Kfast	Time constant fast groundwater discharge [day]
	Kslow	Time constant slow groundwater discharge [day]
	B	Distribution formula fast and slow groundwater discharge [-]
Scenario		Select the Nash-cascade or the Krayenhoff- vd Leur scenario and the number of reservoirs to represent the discharge.

5.2.4 Select Concentration Scheme dialog box

Properties describing the concentration are grouped in a Concentration scheme. All schemes available are shown in the listbox.

Add, Modify	Schemes can be added or modified by using the appropriate button. **Modify** will show the Modify Concentration Scheme dialog box with the schemes values. **Add** will show the same dialog without values.
Copy	Copies the selected schemes in the listbox to make small alterations without changing the original. The copied scheme has the same name and an added number.
Delete	Deletes the selected scheme

5.2.5 Modify Concentration Scheme dialog box

The concentration scheme is in fact a time series scheme. Per date and time a specific value can be given. This dialog box is also used to modify the precipitation and evaporation time series. The units used in the various dialogs are:

| dialog	unit
precipitation	mm/day
evaporation	mm/day
Ammonium	mg N/l
Nitrate	mg N/l
Phosphor	mg/l

There is however also a difference in interpretation of the values by RAM. In a concentration scheme RAM supposes a lineair relation between two given time steps. For the precipitation and evaporation the given values are interpreted as the values "up until now".

for example if entered in dialog:

time	value
1:00	100
3:00	300

The concentration at 2:00 is 200, the precipitation at 2:00 is 300.

A time series can be equidistant (all values one timestep apart), or non-equidistant (the time between values differs). When switching from non-equidistant to equidistant the date and time of the value is changed to fit this equidistant requirement.
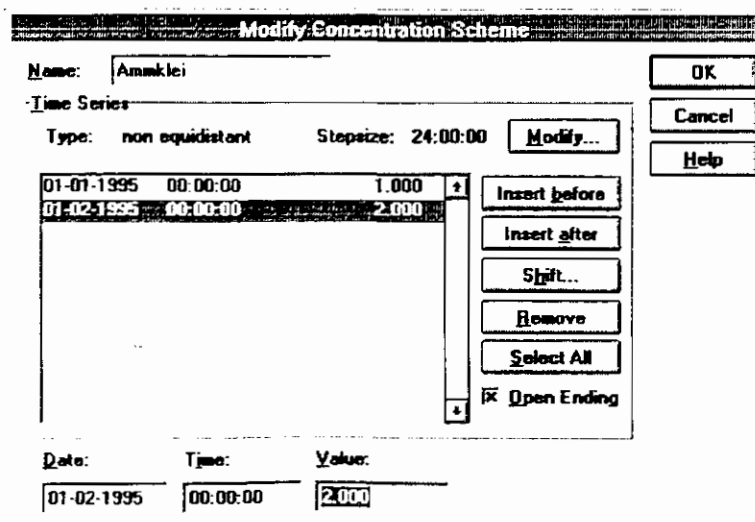
The time series options can be set in the Time Series Settings dialog box, after clicking the **Modify** button.

Modifying the concentration values or the time they occur is done using the following commands:

|	
Insert before	Inserts a new value based on the stepsize before the highlighted line in the listbox.
Insert after	Inserts a new value based on the stepsize after the highlighted line in the listbox.
Shift	Shifts the highlighted lines in the listbox, using the Shift Values dialog box.
	In a equidistant time series the Shift values option can only be used if all values are selected. The series must remain complete, i.e. there must be a value for every time step. Shifting values to another date, and thereby breaking the time chain is not allowed.
Remove	Removes the highlighted lines from the text box.
Select All	Selects all lines in the listbox so that they can be manipulated together.
Open ending	The concentration scheme covers a period. There is also a calculation period (this is set in the Model Calculations Settings dialog box). Open ending completes a concentration scheme (with the last value of the scheme) to fit a concentration scheme to the length of a (longer) calculation scheme.
Import	Enables you to import a time series file saving you the trouble of entering this data manually.

## 5.2.6 Modify Time Series Settings dialog box

The Modify Time Series dialog box enables you to change the properties of a time series. RAM supports both equidistant and non-equidistant time series.
Whenever you change these settings and press OK RAM will ask you to confirm the conversion.
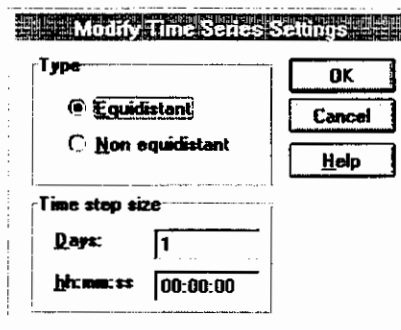

5.2.7 Shift Values dialog box

To shift an existing value to a new date, use this dialog. Choose whether the value has to go forward or backward in time, and specify the day, hour, minutes and seconds of the shift.
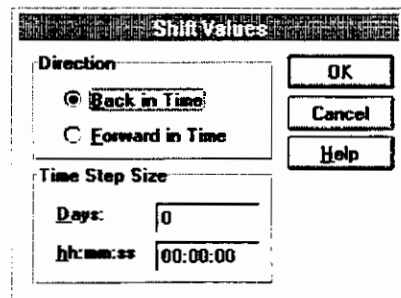
5.2.8 Check Nodes dialog box

The Check nodes dialog box allows you to specify the checked nodes. Checked nodes are used in graphs, logfiles and to import defaults. Checking of nodes can also be done by clicking the nodes in the network window.
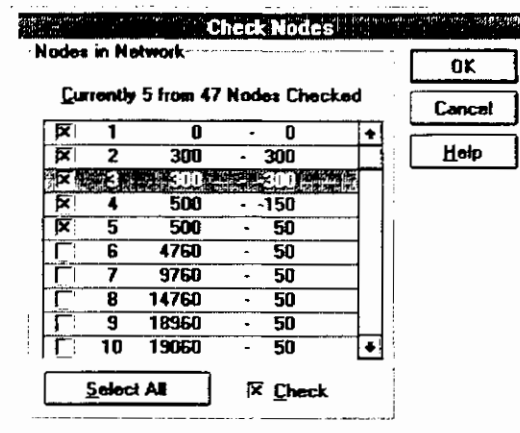
All nodes are listed, the checkbox before each node tells you whether the node is checked. The state of a node can be changed by directly clicking the nodes checkbox in the listbox.
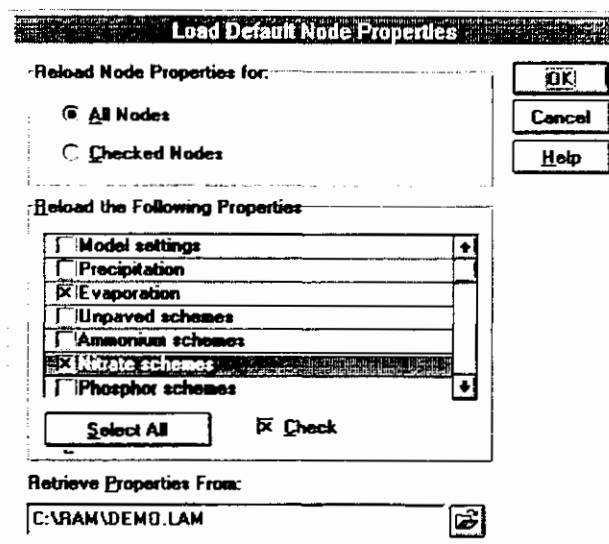
The **Select All** button makes it possible to make a choice for all nodes, by using the Ctrl or Shift button or by dragging the mouse other multiple selection can be made. The **Check** checkbox shows the state of the selected nodes:

- checked means all selected nodes are checked

- gray means that some of the selected nodes are checked

- unchecked means that none of the selected nodes are checked.

You can also use the **Check** checkbox to change the state of the selected nodes.

5.2.9 Load Default Node Properties dialog box

Instead of filling out all node properties, the properties can be loaded from an existing file. A set of defaults can be loaded separately for each group of properties. Some of the properties which can be reloaded are not directly related to nodes. If they are their description in the **Reload the Following Properties** listbox is prefixed by "Node - ".

First you have to specify for which nodes the defaults are to be reloaded, for all nodes or for the checked nodes (see Checked Nodes dialog box and network window).

Then you have to specify which sets of properties have to be reloaded. All groups are listed, the checkbox before each property group tells you whether the property is to be reloaded. The state of a property can be changed by directly clicking the checkbox in the listbox. The **Select All** button makes it possible to make a choice for all properties, by using the Ctrl or Shift button or by dragging the mouse other multiple selection can be made. The **Check** checkbox shows the state of the selected properties:

- checked means all groups are checked

- gray means that some of the groups are checked

- unchecked shows that none of the groups is checked.

You can also use the **Check** checkbox to change the state of the selected properties.

Finally you have to specify the file from which the defaults are to be reloaded. Type the path and the filename. To search the file, use the file open button behind the text box, you can choose the file in the Select Properties From dialog box.

5.2.10 Precipitation dialog box

The precipitation scheme is in fact a time series scheme. Therefore RAM uses a variation of the Modify Concentration Scheme dialog box to modify the precipitation (see page 75).
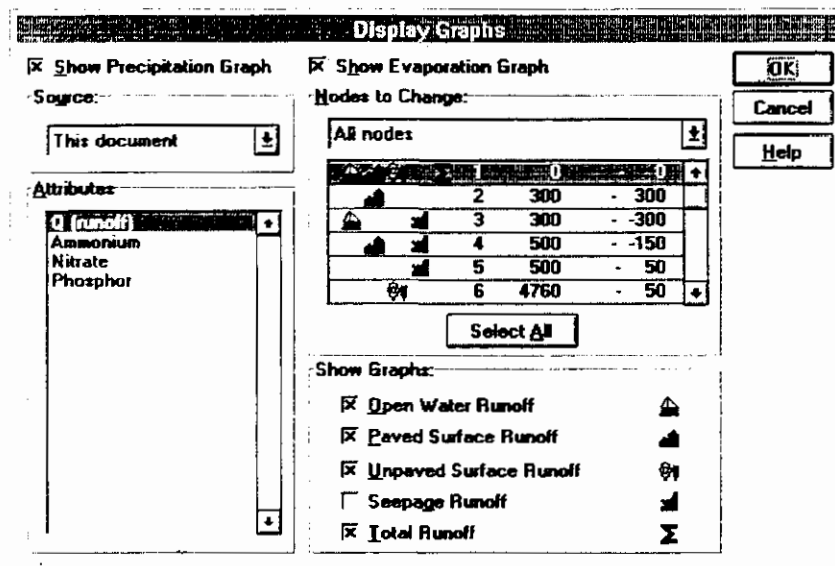
5.2.11 Evaporation dialog box

The evaporation scheme is in fact a time series scheme. Therefore RAM uses a variation of the Modify Concentration Scheme dialog box to modify the precipitation (see page 75).

5.3 View related dialogs

5.3.1 Display Graphs dialog box

The Display Graphs dialog box makes it possible to define what is displayed in the graph window.

Choices that can be made are:

Show Precipitation	Shows the precipitation time series in the graph
Show Evaporation	Shows the precipitation time series in the graph
Source	The source of the graph is the project (This document) or other sources which are available after the selection of Import Reference data. The imported data can be

displayed, together with the data of 'This document'

Nodes to Change   Select in the combobox if All nodes or only checked
                       nodes are to be displayed in the adjoining listbox. In this
                       listbox RAM shows which graphs per node are to be
                       displayed in the graph window.
                       The state of a node can be changed by clicking in the
                       listbox or by using the checkboxes in the **Show Graphs**
                       groupbox.

                       The **Select All** button makes it possible to make a choice
                       for all nodes, by using the Ctrl or Shift button or by
                       dragging the mouse other multiple selection can be made.
                       The graph selections apply to all the selected nodes.

Show Graphs   Use **Show Graphs** to select of the selected nodes in the
                       Nodes to Change listbox, the kind of graph to show.
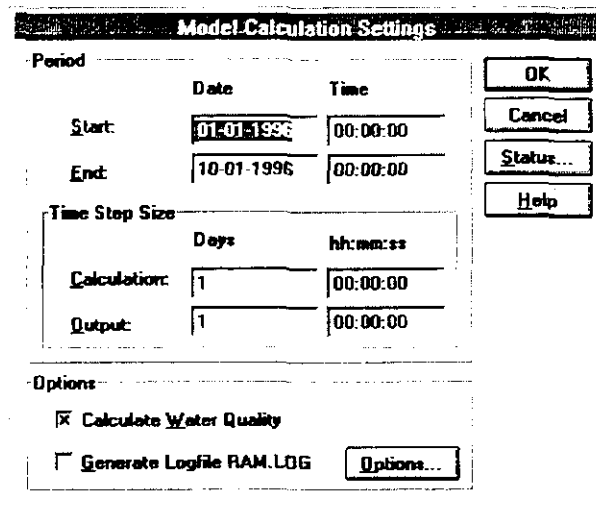
                       The pictures represent:

                       ⏚   Open Water Runoff

                       ◢   Paved Surface Runoff

                       ❀▮   Unpaved Surface Runoff

                       ◢   Seepage Runoff

                       Σ   Total Runoff

The graphs, per node, are shown only when the node is checked. To check the node use the Check Nodes dialog
box, or use the mouse (see Network Window).

5.4 Options related dialogs

5.4.1 Model Calculation Settings dialog box

The calculation settings are subject to the following conditions:

Period   Start   Set the start date and time for the calculation.

          End   Set the end date and time for the calculation.

          Time Step size, Calculation   Set the calculation time step.

          Time Step size, Output   Set the output time step, the output time step must
                                         be a multiple of the calculation time step.

Options   Calculate Water Quality   RAM always calculates the precipitation runoff,

an additional choice is calculating the loads or water quality of Ammonium, Nitrate and Phosphor).

Generate Logfile RAM.LOG	The steps in the calculation can be stored in a RAM.LOG file for calculation checks.
Options	This option enables you to specify the options used for generating the logfile. RAM will display the Options Logfile dialog box.
Status	Shows a status window, which displayes the consequences of the current settings..
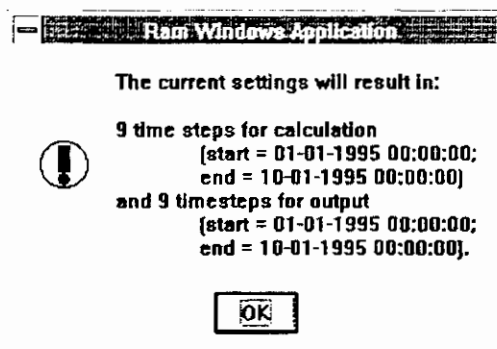
5.4.2 Options Logfile dialog box

You can select the data that is to be included in the logfile in the Options Logfile dialog box.
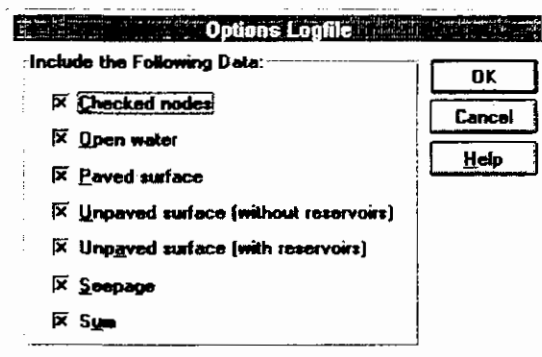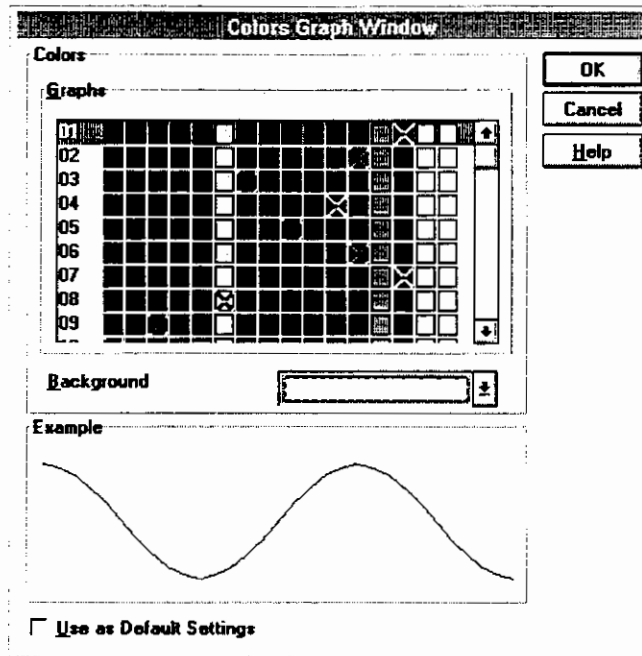

The possible options are:

Checked nodes	Include data on checked nodes only. This options is preferred because it reduces the size of the logfile significantly.
Open water	Include data concerning open water.
Paved surface	Include data concerning paved surface.
Unpaved surface (without reservoirs)	Include data concerning unpaved surface without reservoirs.
Unpaved surface (with reservoirs)	Include data concerning unpaved surface with reservoirs.
Seepage	Include data concerning seepage.
Sum	Include the sum of all surfaces.

5.4.3 Colors Graph Window dialog box

The color of the lines in the graph window can be customized, using the Colors Graph Window dialog box.

The possible options are:

|	
Graphs	A color can be selected for each line in the graph. The lines are listed in the graphs list box. To select a color click a colorbox that lies on the same line as the line number. An example for the chosen line is shown in the **Example** groupbox..
Background	Select the background color for the graph dialog box.
Example	Shows the selected line color for the active line in the **Graphs** listbox.
Use as Default Settings	Instructs RAM to use the current settings as the default settings.

5.4.4 Styles and Colors dialog box

The way in which the network is displayed can be influenced by using the Styles and Colors dialog box.
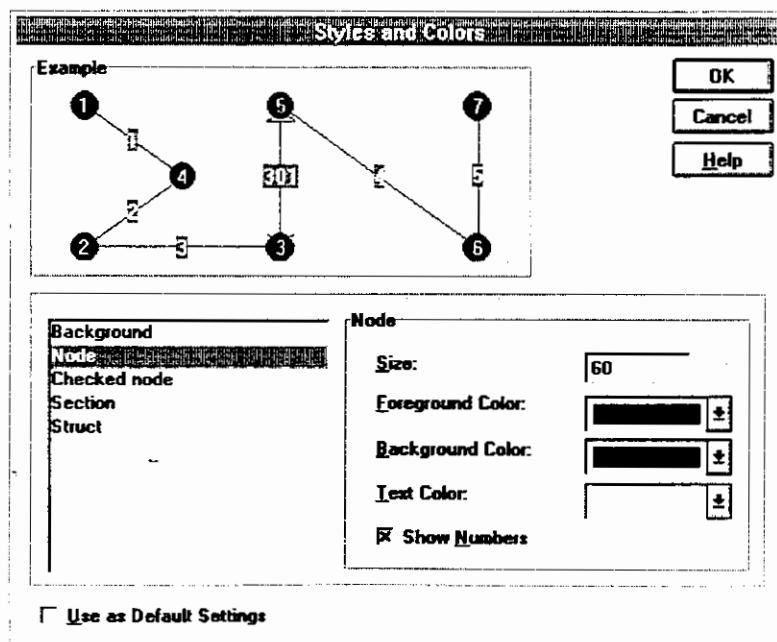
The parts of the network that can be customized are shown in the listbox. The features that can be customized change after selecting a part of the network in the listbox.

The features per network part that can be changed are:

Network part	Feature	Explanation
Background	Background color	Changes the background color of the Network window.
Node	Size	Sets the size of the node representation.
	Foreground color	Sets the color of the border of the node-representation.
	Background color	Sets the fill color of the node-representation.
	Text color	Sets the color of the text in the node (is shown when **Show Numbers** is selected).
	Show Numbers	Shows the numbers in the node representation. This options also applies to the checked nodes.
Checked Node	Foreground color	Sets the color of the border of the checked nodes, so they can be distinguished from the unchecked nodes.
	Background color	Sets the fill color of the checked nodes, so they can be distinguished from the unchecked nodes.
	Text color	Sets the text color of the checked nodes, so they can be distinguished from the unchecked nodes. The Text is shown when the option **Show Numbers**, belonging to the Node settings, is set.
Section	Line color	Sets the color of the section that connects the nodes.
	Text color	Sets the text color of the text belonging to the section that connects the nodes. The text is shown when Show Number is set.
	Text background color	Sets the color of a box around the section text (to highlight it agqinst the background). The text is shown when **Show Numbers** checkbox is set.
	Show Numbers	Shows the numbers belonging to the section that connects the nodes.
Struct	Symbol	Select the symbol for structs. A struct is a connection between nodes that consist of a hydraulic work, to differentiate it from a normal connection: a part of a flow.
	Line color	Sets the line color for a struct
	Fill color	Sets the fill color of a struct.

5.4.5 Import Reference Data dialog box

RAM gives you the opportunity to compare the calculations you make with reference data, from previous calculations or from calculations made in DUFLOW.
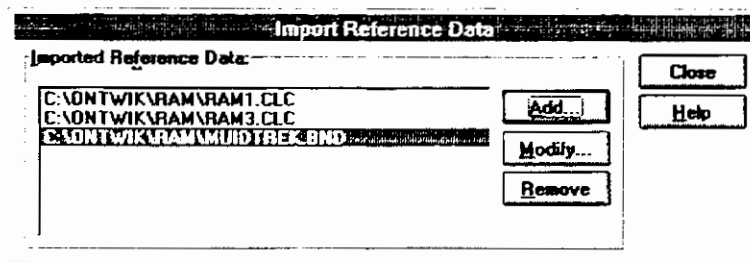
The comparison data have to be stored in a *.CLC-file (a RAM calculation file) or a *. BND-file (a DUFLOW file).

Add	Add a reference data file, after clicking the button an File Open dialog is displayed.
Modify	Select a reference data file (from the File Open dialog box) instead of the highlighted file in the listbox.
Remove	Remove the highlighted reference data file from the imported reference data list.

5.5 Help related dialogs

5.5.1 About RAM dialog box

The About RAM dialog box contains the application name and logo, the RAM version number the copyright statement.
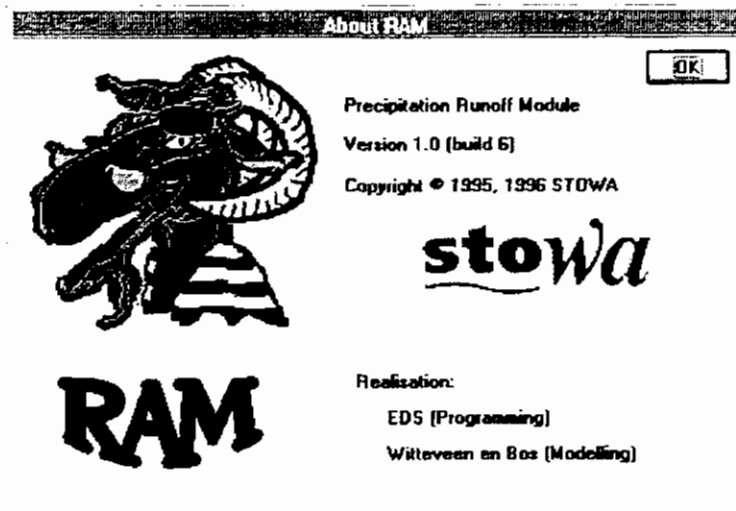
6. Features

6.1 Toolbar

The toolbar is displayed across the top of the application window, below the menu bar. The toolbar provides quick mouse access to many options of RAM,

To hide or display the Toolbar, choose Toolbar from the View menu (ALT, V, T).

| Click	To
	Create a new project.
	Open an existing project. RAM displays the Open dialog box, in which you can locate and open the desired file.
	Save the active project with its current name. If you have not named the project, RAM displays the Save As dialog box.
	Print the active document.
	Zooming tool. Use the zooming tool to show parts of the network in more detail. After selecting the command (from the menu or the toolbar) the cursor will change into a magnifying glass. Dragging the cursor displays a rectangle on your screen. This rectangle represents the area that will be magnified (the rectangle will be blown up until it fills the network window).
	Zoom out. Zooming is usually done in stages, more and more detail of the network is shown. Zooming out lets you retrace these stages. Zoom out works independent from the zooming tool (the zooming tool needn't be selected to zoom out). To zoom out to the unzoomed state use the Entire network command
	Entire Network. The entire network command shows the entire network (before zooming), instead of zooming out in stages (Zoom out command).
	Calculate
	Cascade
	Tile Horizontally
	Tile Vertically
	About RAM. Shows the About RAM dialog box
	Start Help tool, the helpfile will be started automatically after a command is clicked. The description of the chosen topic is shown.

6.2 Status Bar

```
|                                          |CAP :        |     |
```
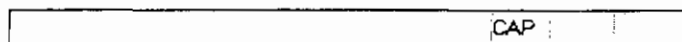
The status bar is displayed at the bottom of the RAM window. To display or hide the status bar, use the Status Bar command in the View menu.

The left area of the status bar describes actions of menu items as you use the arrow keys to navigate through menus. This area similarly shows messages that describe the actions of toolbar buttons as you depress them, before releasing them. If after viewing the description of the toolbar button command you wish not to execute the command, then release the mouse button while the pointer is off the toolbar button.

The right areas of the status bar indicate which of the following keys are latched down:

Indicator	Description
CAP	The Caps Lock key is latched down.
NUM	The Num Lock key is latched down.
SCRL	The Scroll Lock key is latched down.

6.3 Network Window

The network window shows the schematization of waterways. The schematization is built using the following components:

Node	Nodes represent measuring- or calculation points, they comprise information of the surrounding sections and structs.
Section	Waterway that connects nodes
Struct	Hydraulic work as connection between nodes

Zooming and selection
You can zoom in to the network or check nodes using the mouse. The network window supports two modi, selection mode and zoom mode. You can change between these modes with the Zooming Tool command in the edit menu or with the toolbar.
In zoommode you can zoom in to the dragged rectangle (press the left mouse button, track a rectangle and release the button).
In selection mode RAM supports several extentions. It is even possibly to zoom while in selection mode.
In Selection mode the following extentions are supported:

SHIFT key	the nodes in the dragged rectangle will be added to the already checked nodes.
CTRL key	the check status of the nodes in the dragged rectangle will be toggled.
SHIFT+CTRL key	RAM will zoom in to the dragged rectangle. The check status of the nodes will not be altered.

The presentation of the contents of the network window is set in the Styles and Colors dialog box.

A shortcut to the commands that influence the contents of the Network Window is provided. Clicking the right-mousebutton displays a shortcut menu to the dialogs connected to the commands:

Check	Checks or unchecks nodes.
Properties	Modifies the properties of the nodes
Styles and Colors	Sets styles and colors of the network window
Precipitation	Enters precipitation data
Evaporation	Enters evaporation data

The Network Window shares room with the Graph window (they share the workspace of a project window). To make more room for the Network Window use the Splitter.

6.4 Graph Window

The Graph window optionally shows the calculated runoff and loads per node and the precipitation and evaporation.

A shortcut to the commands that influence the contents of the Graph Window is provided. Clicking the right-mousebutton displays a shortcut menu to the dialogs connected to the commands:

Display   Sets the graphs which will be displayed. RAM will
               show the Display Graphs dialog box

Colors   Sets the colors of the graphs

Legend   Shows or hide the Legend window

The Graph Window shares room with the Network window (they share the workspace of a project window). To make more room for the Graph Window use the Splitter.

6.5 Splitter

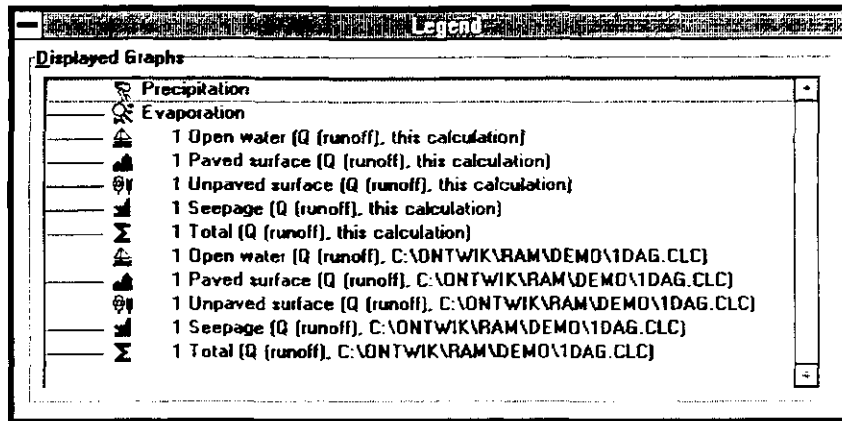The project window is splitted into panes (the network window and the graph window).
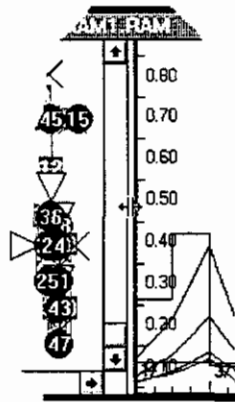
The space relation between the to panes is influenced by the Splitter. This is the vertical bar between the two parts. Moving the mouse above the bar will change the mouse pointer, into a splitter. The bar is moved by dragging the splitter mouse.

6.6 Legend Window

The Legend Windows distinguishes all lines in the Graph Window, by giving the nodenumber and the explanation of the contents.
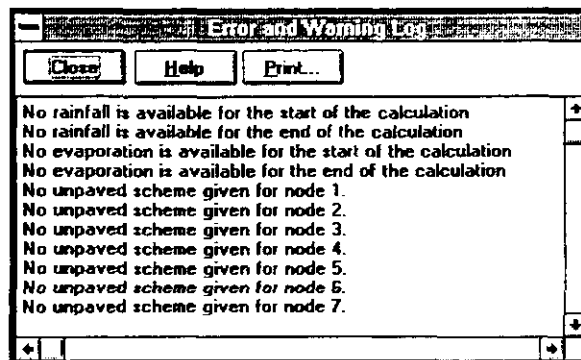
The Legend Window is displayed after selecting the Legend command in the View menu, or in the right mouse button menu in the graph window.

```
┌─[■]─▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓Legend▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓▓─┐
│ ┌Displayed Graphs────────────────────────────────────────────────┐
│ │  ┌──────────────────────────────────────────────────────┐  [▲]
│ │  │  🄋 Precipitation                                       │
│ │  ──── Q̃ Evaporation                                        │
│ │  ──── ⚖  1 Open water (Q (runoff), this calculation)
│ │  ──── ⬛  1 Paved surface (Q (runoff), this calculation)
│ │  ──── ⊛  1 Unpaved surface (Q (runoff), this calculation)
│ │  ──── ⬛  1 Seepage (Q (runoff), this calculation)
│ │  ──── Σ  1 Total (Q (runoff), this calculation)
│ │       ⚖  1 Open water (Q (runoff), C:\ONTWIK\RAM\DEMO\1DAG.CLC)
│ │  ──── ⬛  1 Paved surface (Q (runoff), C:\ONTWIK\RAM\DEMO\1DAG.CLC)
│ │       ⊛  1 Unpaved surface (Q (runoff), C:\ONTWIK\RAM\DEMO\1DAG.CLC)
│ │  ──── ⬛  1 Seepage (Q (runoff), C:\ONTWIK\RAM\DEMO\1DAG.CLC)
│ │  ──── Σ  1 Total (Q (runoff), C:\ONTWIK\RAM\DEMO\1DAG.CLC)
│ │  └──────────────────────────────────────────────────────┘  [▼]
│ └────────────────────────────────────────────────────────────────┘
└────────────────────────────────────────────────────────────────────┘
```

6.9 Error and Warning Log Window

RAM displays the Error and Warning Log window when it detects errors during a time consuming process. This might occur at two points:

• while starting a calculation RAM checks the input data. If it finds any errors it displays the Error and Warning Log dialog box.

• while importing reference data RAM checks if it can match the imported data to the active project.


```
┌─[■]─▓▓▓▓▓▓▓▓▓▓▓▓▓Error and Warning Log▓▓▓▓▓▓▓▓▓▓▓▓▓─┐
│  ┌─────────┐  ┌───────┐  ┌───────┐
│  │ Close   │  │ Help  │  │ Print...│
│  └─────────┘  └───────┘  └───────┘
│ ┌───────────────────────────────────────────────────┐[▲]
│ │ No rainfall is available for the start of the calculation │
│ │ No rainfall is available for the end of the calculation   │
│ │ No evaporation is available for the start of the calculation│
│ │ No evaporation is available for the end of the calculation │
│ │ No unpaved scheme given for node 1.                       │
│ │ No unpaved scheme given for node 2.                       │
│ │ No unpaved scheme given for node 3.                       │
│ │ No unpaved scheme given for node 4.                       │
│ │ No unpaved scheme given for node 5.                       │
│ │ No unpaved scheme given for node 6.                       │
│ │ No unpaved scheme given for node 7.                       │[▼]
│ └───────────────────────────────────────────────────┘
│ [◄] │                                              [►]
└─────────────────────────────────────────────────────┘
```

The following commands are available

Close	Close the Error and Warning Log window.
Print	Print the contents of the the Error and Warning Log window RAM will first display the Print dialog box.

7. File Formats

7.1 BND

Duflow Boundary Conditions files contain the runoff and the loads of the calculation. They are typically used by RAM to import reference data or to export data. For a complete description of this file format see the Duflow 2.0 manual, Appendix E. The following examples explain the file format. Comment lines start with an asterisk (*).

example 1, a non equidistant time series and a constant time series

```
* DUFLOW data file :C:\RAM\RAM.BND
* Flow  Bound. cond./struct ctrl.      program version: 2.03
*2345678901234567890123456789012345678901234567890123456
*
Q               0                                    1
*Q=runoff       timestep : 0-->non equidistant       node number
    950101      0 1.0000
*   date      time value
    950101      2 2.0000
    950105      3 1.5000
    950108      4 2.5000
    950109      5 2.0000
    950121   1030 4.0000
Q                                                    14
*Q=runoff          no timestep -> constant           node number
P    2.5000
```

example 2, equidistant times series for runoff and loads

```
* DUFLOW data file C:\ONTWIK\RAM\TEST.BND
* File generated by RAM application version 1.00.
*2345678901234567890123456789012345678901234567890123456
*
Q            0100 950101    0000                     1
*Q=runoff       timestep                             node number
*               date        time
    0.0144 0.0222 0.0268 0.0329 0.0388 0.0444
    0.0497 0.0549 0.0598 0.0646 0.0691 0.0735
    0.0777 0.0817 0.0855 0.0892 0.0928 0.0962
    0.0994 0.1025 0.1055 0.1084 0.1112 0.1138
    0.1164
*   values, max 6 per line
L            0100 950101    0000           nh4       1
*L=load      timestep                      concentration
*               date        time                     node number
*the combination L and concentration determine the meaning of L
    0.0144 0.0222 0.0269 0.0331 0.0390 0.0447
    0.0501 0.0554 0.0605 0.0654 0.0701 0.0746
    0.0789 0.0831 0.0871 0.0910 0.0948 0.0984
    0.1018 0.1052 0.1084 0.1115 0.1145 0.1173
    0.1201
L            0100 950101    0000           no3       1
    0.0144 0.0222 0.0269 0.0331 0.0390 0.0447
    0.0501 0.0554 0.0605 0.0654 0.0701 0.0746
    0.0789 0.0831 0.0871 0.0910 0.0948 0.0984
    0.1018 0.1052 0.1084 0.1115 0.1145 0.1173
```

```
        0.1201
   L             0100  950101    0000                      p          1
        0.0144  0.0222  0.0269  0.0331  0.0390  0.0447
        0.0501  0.0554  0.0605  0.0654  0.0701  0.0746
        0.0789  0.0831  0.0871  0.0910  0.0948  0.0984
        0.1018  0.1052  0.1084  0.1115  0.1145  0.1173
        0.1201
```

7.2 CLC

Calculation files are used are used by RAM to store calculation results. By default these results are stored in a temporay file that is deleted automatically on closing the project. However in case of large time consuming calculations it can be usefull to store the results so RAM can show them later on. You can force RAM to keep the calculation results in the Configure Project dialog box. The format of this file is private to RAM.

7.3 DAT

See LAM files.

7.4 LAM

The LAM files are called the Node Settings files. These files contain the user settings of a document. The format of this file is private to RAM. This file will be generated by RAM if you save the project. In order to address the contents of the LAM file RAM also generates an index file (*.DAT).

Make sure when you backup your project data also to backup the corresponding *.DAT file.

7.5 LOG

In the logfile RAM can trace its calculations. The logfile generated by RAM is always called RAM.LOG. If you want to compare logfiles you will have to rename them yourself because RAM will overwrite old logfiles without a warning. The logfile is an ASCII text file. The following is an example of a logfile. Since the format of the logfile is trivial it is not explained here. Please refer to the chapter Background (page 2).

```
RAM logfile: created 15-09-1995 03:26:18
Model settings Start 01-01-1995 00:00:00; End.01-02-1995 00:00:0
Stepsizes: calculation 28800, output 28800

Start calculating 47 nodes:

Node 1:


Open water
k = 1.000000, f = 1.000000
Used ammonium scheme Ammklei
Used nitrate scheme Nitklei
Used phosphor scheme Phosklei
exp = 0.716531


   t    Prec.    Evap.    PN:     qt              Qt

   0    10       2        8       2.26775         0.006562

   1    20       1        19      7.010819        0.020286

   2    20       1        19      10.40938        0.03012

   3    20       1        19      12.84455        0.037166
```

7.6 NET

The network file contains a description of the network. The network file is an ASCII text file which is human readable. You can change these files manually or generate them using a dedicated program. RAM cannot generate these files for itself.

The format of these file is the DUFLOW version 2.0 file format for Network files. The following example explains the file format. Comment lines start with an asterisk (*).

```
* Network example; used by Styles and Color dialog
*2345678901234567890123456789012345678901234567890123456
SECT   1        1        1       4    7100   58.68   56.86    45.0    45.0
SECT   2        2        4       2    7100   56.86   55.03    45.0    45.0
SECT   3        3        2       3    5000   53.68   53.04    45.0    45.0
SECT   4        4        5       6    5900   53.04   52.31    45.0    45.0
SECT   4        4        6       7    5900   53.04   52.31    45.0    45.0
*      sectionname                   values ignored by RAM
*               section number
*                        begin node number
*                             end node number

STRU   1        301      3       5        0  55.03  120.00   99.00
*      struction name                 values ignored by RAM
*               struction number
*                        begin node number
*                             end node number
```

All other data in DUFLOW network files is ignored by RAM.

7.7 NOD

The node file contains the nodes of the network. The node file is an ASCII text file which is human readable. You can change these files manually or generate them using a dedicated program. RAM cannot generate these files for itself.

The format of these file is the DUFLOW version 2.0 file format for Node files. The following example explains the file format. Comment lines start with an asterisk (*).

```
* Nodes example; used by Styles and Color dialog
*2345678901234567890123456789012345678901234567890123456
       1        0      200      0E+00  1.00
       2        0        0      0E+00  1.00
       3      200        0      0E+00  1.00
       4      100      100      0E+00  1.00
       5      200      200      0E+00  1.00
       6      400        0      0E+00  1.00
       7      400      200      0E+00  1.00
*      node number                    values ignored by RAM
*               X coordinate of the node
*                         Y coordinate of the node
```

All other data in DUFLOW node files is ignored by RAM.

7.8 RAM

RAM files are project files which contain information about the files used by the RAM project. The project file is an ASCII text file which is human readable. Although you can manually change these files it is not recommended. The format of these file is as follows:

```
<identification>
NODES:<TAB><path of nodes file (NOD)>
NETWORK:<TAB><path of network file (NET)>
RAM_NODES:<TAB><path of PAM settings file (LAM)>
KEEP RESULT:<TAB>[0 is FALSE;1 is TRUE]
RESULT<TAB><path of result file (CLC)>
```

```
GENERATE EXPORT:<TAB>[0 is FALSE;1 is TRUE]
EXPORT<TAB><path of export file (BND)>
```

example of RAM project file:

```
#@RAM#@STUUR
NODES:              C:\DEMO\MARKMOD.NOD
NETWORK:            C:\DEMO\MARKMOD.NET
RAM_NODES:          C:\DEMO\DEMO.LAM
KEEP RESULT:        0
RESULT:             C:\DEMO\DEMO.CLC
GENERATE EXPORT:    0
EXPORT:             C:\DEMO\DEMO.BND
```

7.9 TSS

TSS files contain simple Time Series. The format of these files is ASCII text format. They have a very simple syntax and can be used to import time series into RAM (see the Modify Concentration Scheme dialog box). RAM assumes the time series in these files to be non equidistant. The syntax of these files is:

date<TAB>time<TAB>value

with date in the format dd-mm-yy or dd-mm-yyyy and time in the format hh:mm:ss.

example of an TSS file:

```
1-1-95        0:00:16      1
2-1-95        1:00:16      2
3-1-95        2:00:16      3
4-1-95        3:00:16      4
5-1-95        4:00:16      5
6-1-95        5:00:16      6
```

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Table VII-1: The crop factor according to Makkink (Cultuurtechnisch Vademecum, 1988)

month	April			May			June			July			August			September		
decade	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
grass	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9
cereals	0.7	0.8	0.9	1.0	1.0	1.0	1.2	1.2	1.2	1.0	0.9	0.8	0.6	-	-	-	-	-
maize	-	-	-	0.5	0.7	0.8	0.9	1.0	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2
potatoes	-	-	-	-	0.7	0.9	1.0	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	0.7	-	-
sugar beets	-	-	-	0.5	0.5	0.5	0.8	1.0	1.0	1.2	1.1	1.1	1.1	1.2	1.2	1.2	1.1	1.1
leguminous plants	-	0.5	0.7	0.8	0.9	1.0	1.2	1.2	1.2	1.0	0.8	-	-	-	-	-	-	-
Plant unions	0.5	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	-	-
sowing unions	-	0.4	0.5	0.5	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.7	-	-
chicory	-	-	-	-	-	-	0.5	0.5	0.5	0.8	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1
winter carrots	-	-	-	-	-	-	0.5	0.5	0.5	0.8	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
celery	-	-	-	-	-	0.5	0.7	0.7	0.7	0.8	0.9	1.0	1.1	1.1	1.1	1.1	1.1	-
leeks	-	-	-	-	0.5	0.5	0.5	0.5	0.7	0.7	0.8	0.8	0.8	1.0	0.9	0.9	0.9	0.9
bulb/tube crops	-	-	-	-	0.5	0.7	0.7	0.9	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
pome/stone fruit (fully grown)	1.0	1.0	1.0	1.4	1.4	1.4	1.6	1.6	1.6	1.7	1.7	1.7	1.3	1.3	1.2	1.2	1.2	1.2

Appendix II : Staring Series

Tabel 3.2.4.
Volumefractie water θ (%) in relatie tot de drukhoogte h (cm resp. pF) en de hoeveelheid beschikbaar hangwater (θ_hw) bij 3 waarden van de veldcapaciteit voor bovengronden en ondergronden van de Staringreeks (Wösten e.a., 1987).

θ (%) bij 13 waarden voor |h|, resp. pF

|h|(cm)	0,0	1	10	20	31	50	100	250	500	1000	2500	5000	10000	16000	θ_{hw} bij pF 1,7	2,0	2,3
pF	0,0	0,0	1,0	1,3	1,5	1,7	2,0	2,4	2,7	3,0	3,4	3,7	4,0	4,2	4,2	4,2	4,2
BOVENGRONDEN																	
B1	37,1	36,4	35,7	34,7	28,0	20,1	13,0	9,8	7,4	5,4	4,3	3,4	3,0		25,0	17,1	11,5
B2	43,2	40,1	39,2	38,1	35,1	27,6	20,3	15,5	11,8	8,7	6,7	5,3	4,5		30,6	23,1	17,5
B3	44,9	42,8	41,6	40,6	39,1	34,2	24,9	19,3	15,2	11,5	9,3	7,6	6,7		32,4	27,5	20,3
B4	41,7	39,8	38,2	37,0	34,7	28,8	18,7	12,8	9,6	7,0	5,7	4,7	4,1		30,6	24,7	17,0
B7	40,7	38,0	37,3	36,6	35,6	32,4	25,4	21,7	19,0	16,0	14,0	12,1	11,0		24,6	21,4	15,9
B8	40,1	37,7	36,9	36,2	35,2	32,8	27,4	23,3	19,6	15,9	13,2	11,1	9,9		25,3	22,9	18,8
B10	44,8	40,8	40,1	39,6	38,9	37,7	35,1	31,9	26,3	21,6	18,7	15,8	14,3		24,6	23,4	21,6
B11	51,7	47,2	46,3	45,9	45,2	43,6	39,4	34,4	29,7	24,8	21,7	18,8	17,0		28,2	26,6	23,7
B12	57,8	53,1	52,4	51,7	50,9	49,5	46,4	43,5	40,5	36,2	33,1	30,1	28,1		22,8	21,4	19,2
B16	73,3	67,7	65,8	64,4	62,7	58,9	50,5	40,9	30,3	22,1	17,6	14,5	12,9		49,8	46,0	40,1
B18	71,7	69,8	68,5	67,1	65,2	60,9	53,9	48,6	44,0	38,6	34,6	30,6	27,9		37,3	33,0	27,7
ONDERGRONDEN																	
O1	35,4	31,6	30,3	28,6	24,2	12,1	5,6	3,7	2,7	2,0	1,6	1,3	1,1		23,1	11,0	5,7
O2	38,1	35,4	34,0	32,7	30,4	19,7	9,9	7,3	5,7	4,6	3,9	3,3	2,9		27,5	16,8	9,0
O3	34,7	32,1	30,8	29,5	27,2	19,4	11,1	7,5	5,5	4,1	3,2	2,6	2,3		24,9	17,1	10,7
O4	35,8	34,0	32,9	31,4	29,2	23,2	14,2	9,2	6,2	4,4	3,2	2,8	2,5		26,7	20,7	13,8
O5	33,2	30,3	25,4	19,1	11,4	7,6	4,6	3,5	2,7	2,0	1,6	1,2	1,0		10,4	6,6	4,2
O6	41,2	38,7	37,5	36,4	35,5	33,7	30,3	27,6	25,3	22,2	19,8	17,5	16,4		19,1	17,3	14,8
O8	42,3	38,9	38,3	37,8	37,1	32,6	21,1	17,5	14,9	12,4	10,7	9,3	8,4		28,7	24,2	14,6
O9	41,4	38,2	37,2	36,4	35,3	31,8	22,8	18,7	15,4	12,4	10,6	9,1	8,1		27,2	23,7	16,5
O10	43,9	42,5	41,7	40,9	40,0	38,1	32,0	26,7	20,9	16,6	14,1	11,8	10,4		29,6	27,7	23,3
O11	41,9	40,0	39,3	38,7	38,1	36,5	33,1	29,6	26,2	22,1	19,2	16,6	15,0		23,1	21,5	19,1
O12	49,2	47,8	47,3	47,0	46,4	45,2	41,1	36,7	31,3	26,2	23,1	20,2	18,4		28,0	26,8	24,0
O13	58,0	54,9	54,4	54,0	53,5	52,2	49,9	47,2	43,4	39,0	35,9	32,7	30,2		23,3	22,0	20,4
O15	43,7	40,9	40,3	39,6	38,8	36,9	31,6	25,7	20,7	17,1	12,7	10,2	8,5		30,3	28,4	24,7
O16	87,8	81,9	80,3	78,9	75,5	70,9	56,9	45,0	37,8	29,6	24,4	21,1	18,5		57,0	52,4	42,4
O17	89,3	84,6	83,3	82,2	80,6	76,3	65,0	54,2	43,6	34,4	28,6	23,7	20,9		59,7	55,4	47,2

Tabel 3.2.3.
Indeling naar textuur (in % van de minerale delen), organische-stofgehalte (in % van de grond) en mediaan van de zandfractie (M50) van bouwstenen uit de Staringreeks volgens de textuur-terminologie van het systeem van bodemclassificatie voor Nederland (Wösten e.a., 1987).

Bouwsteen	Leem (%)	Lutum (%)	Organische stof (%)	M50 (μm)
BOVENGRONDEN				
Zand				
B1 leemarm, zeer fijn tot matig fijn zand	0 - 10		0 - 15	105 - 210
B2 zwak lemig, zeer fijn tot matig fijn zand	10 - 18		0 - 15	105 - 210
B3 sterk lemig, zeer fijn tot matig fijn zand	18 - 33		0 - 15	105 - 210
B4 zeer sterk lemig, zeer fijn tot matig fijn zand	33 - 50		0 - 15	105 - 210
B5* grof zand			0 - 15	210 - 2000
B6* keileem	0 - 50		0 - 15	50 - 2000
Zavel				
B7 zeer lichte zavel		8 - 12	0 - 15	
B8 matig lichte zavel		12 - 18	0 - 15	
B9* zware zavel		18 - 25	0 - 15	
Klei				
B10 lichte klei		25 - 35	0 - 15	
B11 matig zware klei		35 - 50	0 - 15	
B12 zeer zware klei		50 - 100	0 - 15	
Leem				
B13* zandige leem	50 - 85		0 - 15	
B14* siltige leem	85 - 100		0 - 15	
Moerig				
B15* venig zand		0 - 8	15 - 25	
B16 zandig veen en veen		0 - 8	23 - 100	
B17* venige klei		8 - 100	16 - 45	
B18 kleiig veen		8 - 100	25 - 70	
ONDERGRONDEN				
Zand				
O1 leemarm, zeer fijn tot matig fijn zand	0 - 10		0 - 3	105 - 210
O2 zwak lemig, zeer fijn tot matig fijn zand	10 - 18		0 - 3	105 - 210
O3 sterk lemig, zeer fijn tot matig fijn zand	18 - 33		0 - 3	105 - 210
O4 zeer sterk lemig, zeer fijn tot matig fijn zand	33 - 50		0 - 3	105 - 210
O5 grof zand			0 - 3	210 - 2000
O6 keileem	0 - 50		0 - 3	50 - 2000
O7* beekleem	33 - 50		0 - 3	
Zavel				
O8 zeer licht zavel		8 - 12	0 - 3	
O9 matig lichte zavel		12 - 18	0 - 3	
O10 zware zavel		18 - 25	0 - 3	
Klei				
O11 lichte klei		25 - 35	0 - 3	
O12 matig zware klei		35 - 50	0 - 3	
O13 zeer zware klei		50 - 100	0 - 3	
Leem				
O14* zandige leem	50 - 85		0 - 3	
O15 siltige leem	85 - 100		0 - 3	
Veen				
O16 oligotroof veen		35 - 100		
O17 mesotroof en eutroof veen		35 - 100		
O18* moerige tussenlaag		15 - 35		

* Aan deze bouwsteen zijn tot op heden onvoldoende metingen verricht om een gemiddelde relatie te kunnen presenteren.

Appendix III : Translation Definitions Dutch - English

Hydrological cycle

Afvoer	discharge
Afvoerbare neerslag	effective precipitation
Afwateringsstelsel	drainage system
Bergingscapaciteit van de onverzadigde zone	storage capacity of the unsaturated zone
Capillaire opstijging	Upward capillary migration /capillary rise
Capillaire zoom	capillary fringe
Depressieberging	Storage in surface depressions
Drain	drain pipe
Drainage-afvoer	drainage
Evaporatie	evaporation
Evapotranspiratie	evapotranspiration
Grondafvoer	ground water discharge
Grondwaterstand	ground water level
Grondwaterstandsdiepte	depth of the groundwater level
Hydrologische kringloop	hydrologic cycle
Infiltratie	infiltration
Infiltratiecapaciteit	infiltration capacity
Interceptie	interception
Kwel	seepage / exfiltration
Neerslag	precipitation
Neerslagintensiteit	precipitation intensity
Neerslagoverschot	precipitation
Netto neerslag	precipitation excess
Onverzadigde zone	unsaturated zone
Ontwatering	drainage
Oppervlakte-afvoer	surface runoff
Percolatie	percolation
Schijnspiegel	perched water table / apparent water table
Schijnspiegelafvoer	interflow
Specifieke afvoer	specific discharge
Stroomgebied	catchment area
Transpiratie	transpiration
Veldcapaciteit	field capacity
Verwelkingspunt	wilting point
Verzadigde zone	zone of saturation
Waterbalans	water balance
Wegzijging	downward seepage
Wortelzone	root zone

Water quality

Dutch	English
Adsorptie	adsorption
Afspoeling	runoff
Denitrificatie	denitrification
Desorptie	desorption
Droge depositie	dry deposition
Fosforbindend vermogen (FVB)	phosphorus fixation capacity
Immobilisatie	fixation / immobilization
Mineralisatie	mineralization
Natte depositie	wet deposition
Nitrificatie	nitrification
Omzettingsprocessen	reaction processes
Uitspoeling	leaching
Vervluchting	volatilization

Appendix IV : Installation Procedure

To install RAM	
1	Insert the RAM program disk into your computer.
2	In Program Manager, choose Run from the file menu, then type A:\SETUP (your drive letter may be different) and click OK.
3	Complete the installation by following the instructions of the Setup program.
4	Start RAM by double clicking the . icon.

files

The installation procedure will install the following files:

location	file
RAM directory	RAM.EXE
(e.g. C:\RAM)	RAM.HLP
	RAMSTS.BMF
	RAMSTS.DAT
	NETWORK.CFG
	NODES.CFG
	DEMO.DAT
	DEMO.LAM
	TESTJE.DAT
	TESTJE.LAM
	TESTJE.NET
	TESTJE.NOD
	MARKMOD.NET
	MARKMOD.NET
Windows system directory	CTL3D.DLL
(e.g. C:\WINDOWS\SYSTEM)	