Chapter 9
Transport Processes between Lake Belau and its Drainage Basin

Winfrid Kluge and Otto Fränzle

9.1 Introduction

Air and water are the fluid media transporting dissolved and particulate mineral and organic substances between terrestrial and aquatic ecosystems. With respect to the physics of such flow processes, two theoretical approaches are distinguished in general. Using Euler’s concept, the multidimensional partial flow transport equations are solved simultaneously for all points in space at a given time. Lagrange’s approach describes mainly the temporal change of tracking particles which can shift along flowlines within catchments and may be subject to transformation processes. Although both approaches, from a theoretical point of view, are equivalent, labouring under the apprehension of non-turbulent flow and yielding compatible results (e.g. in groundwater hydraulics), the Lagrange approach provides a detailed description in direct correspondence with the water and material cycles in ecological systems and catchment areas. Between the origin, e.g. the entry into a terrestrial system, and the spatially distinct and temporally retarded effect in the subordinate systems, e.g. the entry into an aquatic system, a direct correlation is established (Kluge et al. 2003).

9.2 A Path Concept as a System-Linking Methodological Platform

The lateral transport processes which cause the hydrological and hydrochemical interactions between ecosystems can be divided, as shown in Fig. 9.1, into the following categories (the cross-section corresponds to the forest catena of the core area):

1. The aerodynamic drift within the boundary layer between the soil and the atmosphere or the canopy surface and the atmosphere and between the water surface and the atmosphere with particular reference to (1a) wind erosion/sedimentation, (1b) emission, (1c) dry and wet deposition, (1d) litter drift;
2. The overland flow, in the sense of Horton’s runoff (2a) on slopes which either reach the riparian wetland/floodplain or local closed depressions (2b), the
saturation overland flow (2c), due to an infiltration excess and an upwards directed discharge of subsurface water in groundwater-influenced areas, or the overflow of water stored temporarily in overflooded depressions (2d);
3. The interflow within the soil zone where slope-parallel low-permeable layers restrict deeper seepage;
4. The upper subterraneous runoff of oxic, usually younger groundwater which is recharged in the catchment area and mainly emerges at the foot of slopes, in riparian wetlands, and in transition to aquatic systems;
5. The lower subterraneous runoff of anoxic, usually older groundwater which is recharged predominantly in the proximity of the geohydraulic divide and discharged directly into water bodies;
6. The fluctuating exchange processes in riparian wetlands and floodplains during flooding by lakes and running waters;
7. Hydrodynamic processes and displacement of matter in lakes, such as (7a) wind-induced non-periodic currents, (7b) wind-induced periodic waves in the littoral zone, (7c) wave erosion and sedimentation along the shore line, (7d) bioturbation, (7e) diffusion of dissolved matter through the sediment-water contact zone, as well as (7f) a multitude of wind-induced mixing and periodic waves, density-dependent buoyancy processes, and sedimentation and displacement processes in the water body;
8. Active faunal exchange between terrestrial and aquatic ecosystems.

In Fig. 9.1, only the transport processes relevant to Lake Belau are marked. Figure 9.2 summarizes how the vertical and lateral exchange paths between lakes and their surrounding catchment areas are linked; and for the sake of better legibility the number of compartments is deliberately reduced. Waters of different genesis and origin mix in the banks and the water bodies. To reflect the microscale spatial structures of transport processes in sufficient detail, the non-point exchange of matter is divided into two categories, namely diffuse inputs not directly observable and small-point or punctiform such as tile drains, small ditches, springs. From a temporal viewpoint, a distinction between permanent, seasonal, and event-dependent inputs is indicated.

Evaluating the substantial interactions between the catchment and the lake, the following balance terms are of interest: (a) input into the plant-soil or water systems from the atmospheric layer, (b) exchange of matter at the surface, (c) near-surface exchange within the soil zone or littoral sediments, (d) upper groundwater exchange, (e) lower groundwater exchange, (f) exchange of matter between littoral and pelagial.

In this connection the retention coefficients $R$ as defined below are useful for comparisons of the material balance and source or sink functions of individual boxes, compartments, or entire catchments, respectively. They are derived from the equation:

$$R = \frac{[(\text{external matter input} - \text{external matter output})/\text{external matter inputs}]}{\times 100 \, \%}$$

In addition to the lateral material flows, the vertical inputs and outputs through the soil surface (deposition, fertilization, harvest) are added to the external exchange fluxes. The internal transformations, e.g. enrichment or mineralization of organic