

# International Commission for the Hydrology of the Rhine Basin

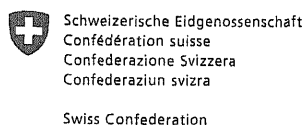
## Erosion, Transport and Deposition of Sediment - Case Study Rhine -

Edited by:  
Manfred Spreafico  
Christoph Lehmann

National coordinators:  
Alessandro Grasso, Switzerland  
Emil Gölz, Germany  
Wilfried ten Brinke, The Netherlands

With contributions from:  
Jos Brils  
Martin Keller  
Emiel van Velzen  
Schälchli, Abegg & Hunzinger  
Hunziker, Zarn & Partner

Contribution to the International Sediment Initiative of UNESCO/IHP



# Content

Introduction .....	1
1 Description of the Rhine River Basin .....	7
1.1 Overview .....	7
1.2 Longitudinal and cross-sectional profiles .....	8
1.3 Human impact .....	11
1.3.1 Hydraulic Works .....	11
1.3.2 Reservoirs and hydropower .....	20
1.3.3 Water supply .....	24
1.3.4 Water quality .....	26
1.4 Population .....	30
1.5 Land use .....	30
1.6 Hydrometeorology .....	31
1.6.1 Climate and Meteorology .....	31
1.6.2 Hydrology .....	33
1.6.2.1 Runoff regime of the River Rhine .....	33
1.6.2.2 Influence of climate change on the runoff regime .....	36
1.7 Travel times .....	40
1.8 Hydrogeology .....	42
1.9 Morphological landscape structure .....	43
1.10 Soils .....	44
2 Users .....	47
2.1 Stakeholders of small alpine catchments .....	47
2.1.1 Needs for protection (mainly natural hazards, soil loss) .....	47
2.1.2 Power and drinking water supply (reservoir sedimentation, abrasion of turbines etc.) .....	48
2.1.3 Construction (use of sediments, dredging) .....	48
2.1.4 Other uses (habitat protection, recreation, environmental protection) .....	48
2.2 Stakeholders of large lowland catchments .....	49
3 Problems related to sediment management .....	51
3.1 Torrents and small Alpine watersheds .....	51
3.2 Large river systems .....	52
3.2.1 Switzerland .....	52
3.2.2 Germany .....	52
3.2.3 The Netherlands .....	54
3.3 Lakes .....	55
4 Necessary sediment observation .....	57
4.1 Switzerland .....	57
4.1.1 Torrents .....	57
4.1.2 Rivers .....	58
4.2 The Netherlands .....	60
4.2.1 Lakes .....	61
4.3 Reservoir Sedimentation .....	62
4.3.1 The Problem of Reservoir Sedimentation .....	62
4.3.2 Consequences of reservoir sedimentation .....	62
4.3.3 Sedimentation rate .....	63
4.3.4 Reservoir sedimentation by turbidity currents .....	64
4.3.5 Measures against reservoir sedimentation .....	64

4.3.5.1	Measures in the catchment area .....	65
4.3.5.2	Control of sedimentation within the reservoir.....	65
4.3.5.3	Measures at the dam.....	66
4.3.6	Today's needs for an approach for Reservoir planning.....	67
4.3.7	Examples .....	68
4.3.7.1	Obstacles: Submerged Dams in Lake Grimsel.....	68
4.3.7.2	Venting: Hydro Power Sarganserland.....	70
4.3.7.3	Bypass-tunnel: Pfaffensprung .....	71
4.3.7.4	Bypass-tunnel: Runcahez .....	73
4.3.7.5	Sediment evacuation through power intake: Gübsensee.....	74
5	Available sediment data .....	77
5.1	Switzerland.....	77
5.1.1	Historic background .....	77
5.1.2	Sediment observations today.....	77
5.2	Germany .....	80
5.2.1	Historical Background.....	80
5.2.2	River bed .....	81
5.2.2.1	Geometry .....	81
5.2.2.2	Geology .....	82
5.2.3	Sediment transport.....	84
5.2.3.1	Bed load.....	84
5.2.3.2	Suspended load.....	85
5.2.4	Grain size.....	86
5.2.5	Petrographic composition.....	86
5.2.6	Data storing .....	87
5.3	The Netherlands .....	89
5.3.1	Historical background .....	89
5.3.2	Bed levels .....	90
5.3.3	Available data on sediment transport.....	90
5.3.4	Available data on grain size .....	90
6	Monitoring equipments and methods.....	93
6.1	Switzerland.....	93
6.1.1	Bed load.....	93
6.1.2	Suspended sediment .....	93
6.1.3	Turbidity.....	94
6.1.4	Suspended solid load.....	95
6.2	Germany .....	96
6.2.1	Geometry of the river bed .....	96
6.2.2	Geology and sedimentology of the river bed .....	96
6.2.3	Bed load.....	98
6.2.4	Suspended load.....	99
6.2.4.1	Permanent monitoring stations.....	99
6.2.4.2	Cross-section measurements .....	100
6.3	The Netherlands .....	101
6.3.1	Riverbed .....	101
6.3.2	Bed load.....	101
6.3.3	Suspended load.....	103
7	Estimation Techniques .....	105
7.1	Switzerland.....	105
7.1.1	Recommendation for the assessment of sediment yield in mountain streams ..	105

7.2	Germany .....	109
7.2.1	Estimation of sediment loads in the German Rhine .....	109
7.2.1.1	General remarks .....	109
7.2.2	Bed load.....	110
7.2.3	Suspended sand load .....	110
7.2.4	Total suspended load and wash load .....	111
7.2.5	Sediment balance and sediment budget .....	111
7.2.6	Comparison of hydrologic, geometric, and sediment transport data.....	114
7.2.7	Morphological models.....	115
7.3	The Netherlands .....	116
8	Legal, administrative and organizational aspects.....	119
8.1	Laws .....	119
8.1.1	Switzerland.....	119
8.1.2	Germany .....	119
8.1.3	The Netherlands .....	120
8.2	Regulations.....	120
8.2.1	Switzerland.....	120
8.2.2	Germany .....	121
8.3	Bilateral and multilateral agreements and treaties .....	121
8.4	Cooperation in international River basin committees .....	121
8.5	Organizations responsible for monitoring.....	122
8.5.1	Switzerland.....	122
8.5.2	Germany .....	122
8.5.3	The Netherlands .....	123
9	Selected recommendations concerning sediment management .....	125
9.1	Flushing and emptying dammed waters.....	125
9.2	Extraction of gravel, sand and other materials from water courses .....	126
10	Rhine sediment quality and its management.....	127
10.1	Sediment quality and assessment .....	127
10.2	Trends in Rhine sediment quality.....	128
10.3	Contaminated sediment re-suspension risks .....	129
10.4	Sediment management .....	130
10.5	Towards a management plan for contaminated sediments.....	130
10.6	Preliminary findings SEDI group.....	132
11	Examples of sediment studies .....	135
11.1	Switzerland.....	135
11.1.1	River Alpine Rhine.....	135
11.1.2	Sediment balance in the Thur catchment area.....	148
11.1.3	Reduction of erosion in the Emme river: Study „Emme 2050“ .....	158
11.1.4	Assessment of sediment yield in the Weisse Lütschine, Canton of Bern .....	180
11.2	Germany .....	182
11.2.1	Bedload management at the Rhine River.....	182
11.2.2	Selective transport and dispersion along the Upper Rhine – results of a long term field test using a petrographic tracer .....	188
11.2.3	Suspended sediment transport and sediment management in the impounded section of the Upper Rhine.....	195
11.3	The Netherlands .....	203
11.3.1	Study German – Dutch border .....	203
11.3.2	Morphological behaviour of bifurcations in the Dutch Rhine river system.....	204
11.3.3	Sediment budget of the Dutch Rhine River system .....	206

12 Literature .....	209
General Information about the International Commission for the Hydrology of the Rhine basin (CHR).....	218
Publications of CHR.....	219