2019-numeric-hydraulic-1D-discharge-modelling

This report is an addition to the *README.md* file in the project folder and should be enquired together. The report shows additional information about the project, the investigation area, the scientific background and the results.

Project overview

This project is part of the author's master thesis about "Discharge measurements in alpine rivers - Opportunities of numeric, hydraulic stage-discharge-relationships". The whole project has been developed in partnership with the Institute of Geography, department of hydrology and the hydropower company Kraftwerke Oberhasli AG (KWO).

To pursue water management construction, precise stage and discharge measurements have a great importance *(Maniak 2010: 59).* The KWO as producer of renewable energy with hydropower depends on accurate stage-discharge-relationships (P/Q-relationships) in three aspects:

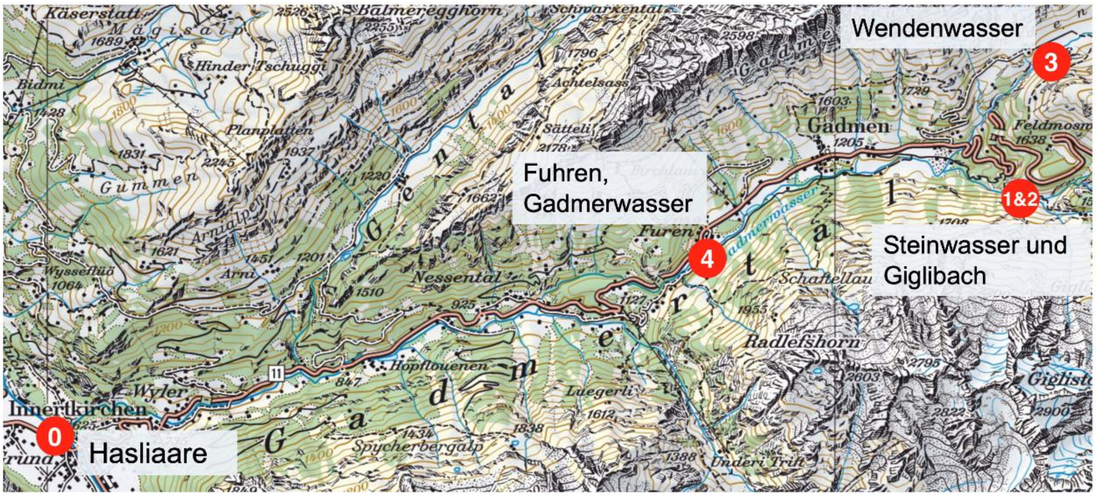
(I) Legal aspects: P/Q-relationships are necessary concerning new concession agreements *(GSchG, Art. 31-33)*, restructuring of residual water *(GSchG, Art. 80)* and restructuring of hydropower *(GSchG, Art. 39a, 43a).*

(II) Operational aspects: Discharge data were required to control the inflow into the hydroelectric power stations, operation optimisation and for flood management.

(III) Strategical aspects: Those aspects are important for hydropower operating companies concerning adaptation to climate change, control the dimensions of the plants and to calibrate hydrological models.

The establishment of manually measured P/Q-relationships is time- and cost-intensive and they need to be redone after a change in the channel cross section (i.e. through debris flow or flood). The idea of this project / master thesis is to calculate the P/Q-relationships with numeric, hydraulic modelling in the two dimensions 1D and 2D. The 1D model was developed in the seminar geodata analysis.

Investigation area



The investigation area in the Haslital.

Scientific background

Stage and discharge measurements are basis to investigate the discharge hydrograph. The hydrograph on the other hand is the evidence to examine the surface water availability, which is major for the hydrological balance *(Maniak 2010: 56, Hölting und Coldewey 2013: 92)*. Stage and discharge measurements are also requirements for the management of water provision systems and the simulation of hydrological processes *(Maniak 2010: 59, Morgenschweis 2018: 2, 26).* Water-level measurements are common with many different measuring systems. Today water-levels were mostly measured continuously with i.e. pressure probes *(Maniak 2010: 56, Oertel et al. 2011: 390, Morgenschweis 2018: 2).* Generally water-level measurements serve to indirectly detect the discharge *(Maniak 2010: 59).* Direct discharge measurements are time- and cost-intensive *(Maniak 2010: 60, Wittenberg 2011: 25).* The more widespread indirect discharge measurements were analysed with the flow velocity and cross section area, what can be done with numeric-hydraulic calculations *(Morgenschweis 2018: 117, Maniak 2010: 60, Morgenschweis 2018: 416ff).*

Discharge measurements at a cross section with an integrated pressure probe at different water-levels enable to generate the average relationship between water-level (P) and discharge (Q). The P/Q-relationship makes it possible to determine the discharge for every measured water-level (Herschy 1998, Maniak 2010: 69, Wittenberg 2011: 21,25, Patt und Gonsowski 2011: 25, Kumar 2014: 1079, Morgenschweis 2018: 26, 416–417).

Results and interpretation

Figure 1 and 2 illustrates the output out of the python script for a cross section in the river Hasliaare. Another edition of a different river is shown in the appendix 1.

Pegel [m]	A [m^2]	P [m]	Rhy [m]	Q [m^3/s]
0.1	0.067	1.361	0.049	0.024
0.11	0.08	1.424	0.056	0.031
0.12	0.094	1.487	0.063	0.039
0.13	0.108	1.55	0.07	0.048
0.14	0.123	1.613	0.076	0.058
0.15	0.138	1.676	0.082	0.068
0.16	0.154	1.726	0.089	0.08
0.17	0.17	1.773	0.096	0.093
0.18	0.19	2.396	0.079	0.092
0.19	0.215	2.896	0.074	0.099
0.2	0.246	3.593	0.068	0.107
0.21	0.285	4.531	0.063	0.118
0.22	0.331	4.95	0.067	0.142
0.23	0.38	5.356	0.071	0.17
0.24	0.438	5.955	0.074	0.2
0.25	0.504	7.011	0.072	0.227
0.26	0.573	7.233	0.079	0.275
0.27	0.643	7.335	0.088	0.331
0.28	0.714	7.437	0.096	0.39
0.29	0.786	7.54	0.104	0.454
0.3	0.859	7.663	0.112	0.52
0.31	0.933	7.801	0.12	0.59
0.32	1.008	7.938	0.127	0.664
0.33	1.085	8.076	0.134	0.741
0.34	1.162	8.217	0.141	0.822
0.35	1.242	8.5	0.146	0.898
0.36	1.326	8.942	0.148	0.968
0.37	1.413	9.402	0.15	1.041
0.38	1.506	9.918	0.152	1.116
0.39	1.603	10.493	0.153	1.194
0.4	1.706	11.135	0.153	1.273
0.41	1.816	11.757	0.154	1.362
0.42	1.931	12.204	0.158	1.472
0.43	2.055	13.104	0.157	1.557
0.44	2.183	13.433	0.162	1.694
0.45	2.313	13.71	0.169	1.84
0.46	2.446	13.966	0.175	1.995
0.47	2.58	14.015	0.184	2.175
0.48	2.714	14.063	0.193	2.362
0.49	2.849	14.112	0.202	2.555
0.5	2.984	14.16	0.211	2.754

Figure 1 Resulting table with the calculated cross section area (A), wetted perimeter (P), hydraulic radius (Rhy) and the discharge (Q) for different water-levels.

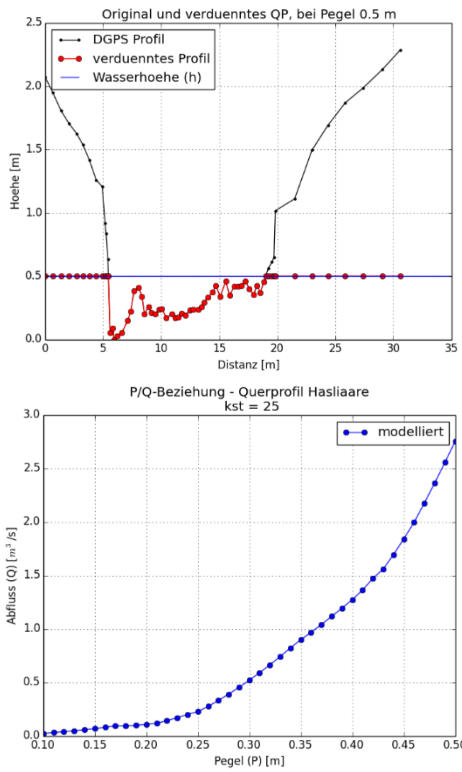


Figure 2 Profile of the Hasliaare at a water-level of 50cm. The red line is the investigated profile sequence. Picture below shows the plot of the P/Q-relationship with kst = 25

The script and its calculations for the resulting P/Q-relationship have been tested manually with a positive comparison. For shallow and laminar flowing rivers like the Hasliaare the modelled P/Q-relationship is comparable with the manually measured relationship and represents a good method to create P/Q-relationships with little time- and cost-intensity (Figure 3).

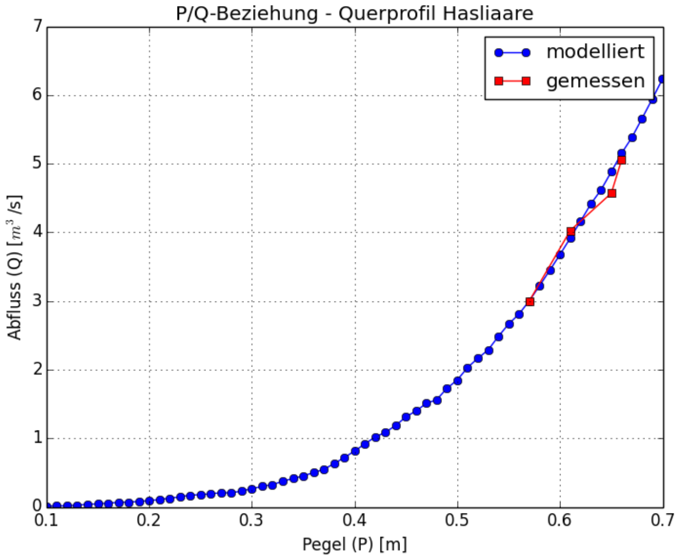


Figure 3 P/Q-relationship of the Hasliaare. The blue dots show the model output and the red dots show the manually measured discharges.

When it comes to steeper and more turbulent rivers like the Wendenwasser, the one-dimensional model cannot cover the manually measured discharges (Figure 4).

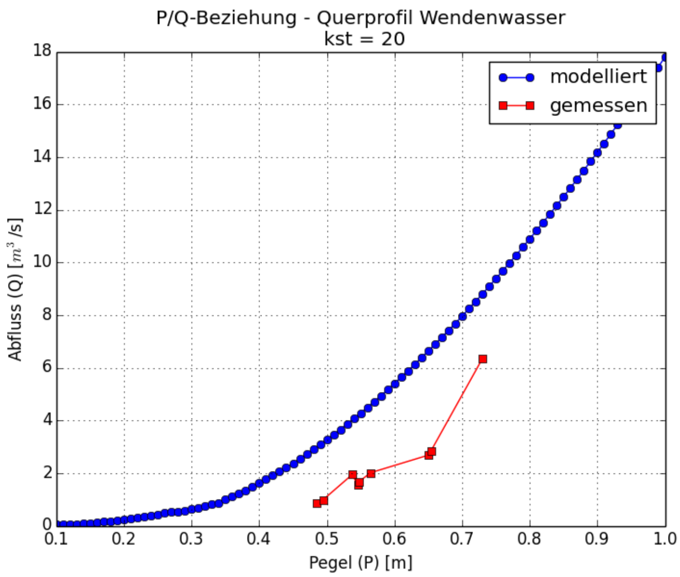


Figure 4 P/Q-relationship of the Wendenwasser. The blue dots show the model output and the red dots show the manually measured discharges.

The problem in this case is the fact, that one-dimensional modelling assumes that the Strickler value (kst) and the average flow velocity (vm) is equal in the whole river cross section, what is not the case. The high Strickler-sensitivity of this model is a further disadvantage when it comes to alpine rivers.

As a next step to improve the P/Q-relationship in alpine rivers the author will imbed the river cross sections into the software BASEMENT to investigate if the Strickler-sensitivity can be lowered by using different Strickler values for the riverbed and the riverbank. Then the P/Q-relationships will be calculated using two-dimensional modelling, which considers the horizontal flow velocity and a higher resolution of the river morphology.

Sources

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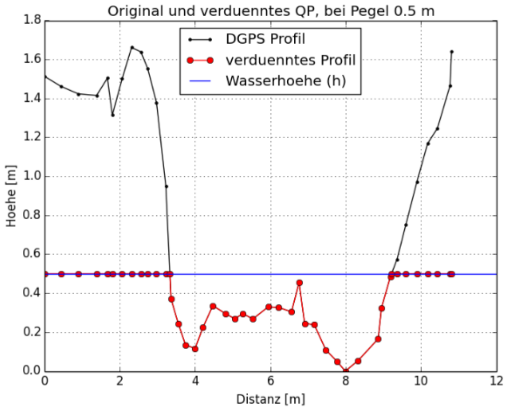
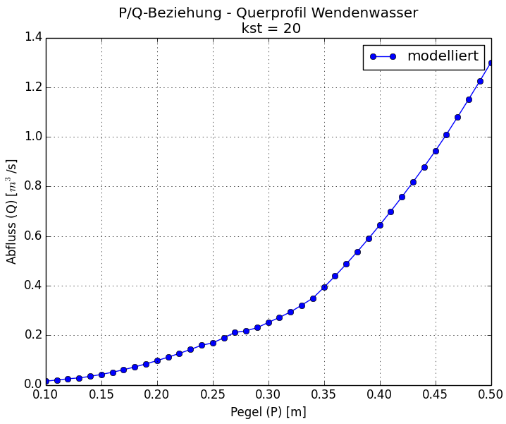
Appendix

Appendix 1

Pegel [m]	A [m^2]	P [m]	Rhy [m]	Q [m^3/s]
0.1	0.053	1.05	0.05	0.015
0.11	0.063	1.145	0.055	0.019
0.12	0.075	1.222	0.061	0.024
0.13	0.089	1.515	0.059	0.028
0.14	0.105	1.688	0.062	0.034
0.15	0.122	1.805	0.067	0.042
0.16	0.14	1.921	0.073	0.051
0.17	0.159	2.018	0.079	0.061
0.18	0.179	2.102	0.085	0.072
0.19	0.199	2.181	0.091	0.084
0.2	0.221	2.26	0.098	0.098
0.21	0.243	2.34	0.104	0.112
0.22	0.265	2.419	0.11	0.127
0.23	0.288	2.5	0.115	0.142
0.24	0.312	2.578	0.121	0.159
0.25	0.339	2.898	0.117	0.169
0.26	0.367	2.965	0.124	0.19
0.27	0.395	3.033	0.13	0.211
0.28	0.425	3.495	0.122	0.218
0.29	0.46	3.906	0.118	0.23
0.3	0.499	4.188	0.119	0.251
0.31	0.539	4.538	0.119	0.272
0.32	0.584	4.92	0.119	0.294
0.33	0.632	5.252	0.12	0.321
0.34	0.685	5.666	0.121	0.349
0.35	0.739	5.731	0.129	0.393
0.36	0.793	5.796	0.137	0.439
0.37	0.847	5.861	0.145	0.487
0.38	0.902	5.919	0.152	0.537
0.39	0.958	5.976	0.16	0.589
0.4	1.014	6.033	0.168	0.643
0.41	1.07	6.09	0.176	0.7
0.42	1.126	6.147	0.183	0.758
0.43	1.183	6.204	0.191	0.817
0.44	1.241	6.261	0.198	0.879
0.45	1.298	6.318	0.205	0.942
0.46	1.356	6.36	0.213	1.009
0.47	1.415	6.389	0.221	1.079
0.48	1.473	6.417	0.23	1.151
0.49	1.531	6.447	0.238	1.225
0.5	1.59	6.48	0.245	1.3

Resulting table with the calculated cross section area (A), wetted perimeter (P), hydraulic radius (Rhy) and the discharge (Q) for different water-levels at the river Wendenwasser.





Profile of the Wendenwasser at a water-level of 50cm. The red line is the investigated profile sequence. Picture below shows the plot of the P/Q-relationship with kst = 20.