[64] THE WBT METHOD: WATER BALANCE APPROACH TO ESTIMATE LONG-TERM WATER INFLOW INTO TUNNELS

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Introduction

In underground projects estimation of expected water inflow during and after construction is always requested. An estimation of this value is usually given by analytical approach (Goodman et al. 1965; El Tani 2003; Perrochet and Dematteis 2007; Preisig et al. 2013) and/or numerical calculations (Anagnostou 1995; Molinero et al. 2002; Zangerl et al. 2003), considering hydrodynamic parameters of the rock mass such as permeability, water head, and storage coefficient. The knowledge on those parameters is very often poor along the tunnel alignment, because of the little number of boreholes and hydraulic tests. The geological complexity, and depth of the tunnel, increase uncertainty on the distribution of the hydrodynamic parameters. In those cases the estimation of water inflow should always be verified by an inverse hydrological water balance. The hydrological water balance could be described by the relationship I=P-R-ETR, where I is the infiltration, P the rainfall or snow melting, R the runoff, and ETR the evapotranspiration. The calculation of the infiltration amount in the basins overlying the tunnel allows to obtain a rough estimation of theoretical maximum water inflow. The runoff is obtained from hydrological measurements in waterways, or can be indirectly estimated considering the parameters of the basins conditions at surface such as the energy of the slope, rock exposure, land use and type of vegetation. The influences of both geological and structural underground conditions, although it can significantly affect this value, are not taken into account in the inverse hydrological water balance.

The present work proposes a new classification method called WBT (Water Balance approach to estimate long-term water inflow into Tunnels). The WBT method integrates classical hydrological water balance with geological, structural and spatial-geometric parameters of the massif crossed by the tunnel. The result is the estimation of the long-term groundwater inflow into tunnel.

Main Body

WBT method consists in:

a. define the hydrogeological basins overlying the tunnel;
b. carry out the hydrological water balance in each basin, to obtain the average annual effective infiltration on the whole area of the basin under passed by the tunnel, expressed in m^3/s;
c. subdivide the tunnel in sectors. Each sector is the projection of the basin limits on the tunnel alignment in plan;
d. assign to each sector a rating from 0.5 to 3 according to geological underground conditions, as defined in Table 1 (overburden, permeability, high permeability channels, sector length, basin area);
e. summarize, for each sector, the contribution of each parameters of Table 1, to obtain the WBT rating. The WBT rating is further classified in Table 2 to define the reduction of effective infiltration. The reduction range indicated in Table 2 is estimated, and will be refined with the calibration on real data, still in progress;
f. apply to each sector the reduction indicated in Table 2 to the average annual effective infiltration calculated at point b). This is the long-term water inflow estimation into the tunnel according to WBT method.

WBR rating	Contribution of effective infiltration to the tunnel	Reduction of the water balance effective infiltration value
4-6	Low	40-70%
6,5-9	Good	10-40%
9,5-12	Very good	0-10%

Tab.2 – Reduction of water balance effective infiltration value depending on WBT.

The method has been implemented and is being validated in an ongoing twin tube excavation (8 km each tube) in the Chilean Andes.

In the first 2.5 km, 3 out of 16 identified hydrological sectors were crossed. For these three sectors, the calculated WBT rating ranged from 7 to 7.5, so, to estimate the expected long-term inflow into the tunnel, was applied the 20% reduction on the infiltration value of the hydro geological balance. Therefore, from an initial infiltration value of 110-120 L/s, a stabilized inflow value of 88-96 L/s after the application of

the reductions according with WBT ratings was obtained. Those results are under control and verification by means of monitoring the groundwater inflow discharge into tunnel. This will allow the calibration. Currently, the flow rate recorded in the tunnel for these three sectors, is equal to 90-95 L/s.
The first results of WBT application demonstrate a good response. The quickly application and the ease of retrieval and control of the input data, makes WBT an interesting and innovative method, which complements and improves the hydrogeological studies applied in tunneling. WBT should be understood as a complementary method to classical analytical and numerical approaches. In order to check and verify by a different way the forecast of water inflow into tunnels.

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PARAMETERS DEFINITION	EFFECTIVE INFILTRATION RATING		
1) Overburden The greater is the overburden, the lower is the contribution of effective infiltration to the tunnel	High > 500m	Medium 100 to 500 m	Low <100m
Rating	*1*	*2*	*3*
2) Permeability The lower is the mean permeability of the massif, the lower is the contribution of effective infiltration to the tunnel	Very low to Medium	Medium to High	High to very High
Rating	*1*	*2*	*3*
3) High permeability channels Fault zone, main joint, karstic layer connecting the surface with the tunnel, increases the contribution of effective infiltration to the tunnel	No fault zone or karst	Minor fault zones or main joints	Major fault zone, master joints and/or karstic terrains
Rating	*1*	*2*	*3*
4) Sector lenght The longher is the lenght of the sector (projection of the basin limits on the tunnel alignment in plan), the the bigger is the potential of inflow into the tunnel	< 50 m	50 to 500 m	> 500 m
Rating	*0,5*	*1*	*1,5*
5) Basin area If the tunnel has an elevation higher than the lower point of the basin, then the bigger is the percent of the upper area of the basin, the higher is the contribution of effective infiltration to the tunnel	Low rate (< 30%)	Low rate (30% to 60%)	High rate (> 60%)
Rating	*0,5*	*1*	*1,5*

Tab.1 – Classification parameters affecting the contribution of effective infiltration to the tunnel and WBT ratings.

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FOREWORD

FLOWPATH 2014, the National Meeting on Hydrogeology, Viterbo 2014, follows up on previously organized and successful meeting FLOWPATH 2012 held in 2012 in Bologna. According to the aim of the 1st Edition, the conference will be an opportunity for Italian hydrogeologists to exchange ideas and knowledge on diversified groundwater issues. The IAH Chapter organized the 2nd Edition to ensure the continuation of this stimulating debate within the scientific and professional community, giving priority to proposals and ideas of young hydrogeologists.
This Abstract Volume contains abstracts of technical oral and poster contribution accepted to the FLOWPATH 2014, and of the invited keynotes presentations. The abstracts were evaluated by the members of the Scientific and Organizing Committees. More than 80 abstracts have been submitted for oral or poster presentations, mainly but not only by Italian hydrogeologists. Significant and interesting contributions were also received from many counties such as Algeria, Austria, Belgium, Canada, Egypt, France, Germany, United Kingdom, Guatemala, Portugal, Russia, Serbia, Slovenia, Spain, Switzerland, Tunisia, USA.

FLOWPATH 2014 focuses on four themes of great importance:

1. Contaminant Hydrogeology,
2. Groundwater Quality Protection,
3. Hydrogeology of Mineral and Thermal Waters,
4. Climate Change and Groundwater Sustainability.

The Table of Contents of the Abstract Volume is organized according to the four topics of the conference. Within each topic, the abstract of the keynote lecture opens the Session and is followed by the technical contributions in alphabetical order of the first Author’s name. In order to facilitate the use of the volume, the Index of Authors is placed at the end of the volume.
The printing of this volume was made possible thanks to the contribution of the Executive Committee and of the Department of Ecological and Biological Sciences, Università degli Studi della Tuscia.

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