Universität Basel

Applied & Environmental Geology

Thermal Potential of Urban Tunnel Infrastructures in Unconsolidated Rock Groundwater Resources

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Motivation

Increased groundwater temperatures can be observed in many urban areas (Fig. 1). The recycling of this 'waste heat' represents a unique potential for shallow geothermal energy systems (SGE), e.g. through tunnel infrastructures.

Depending on the type of tunnel infrastructure (motorway or railway) and its location, taking into account geological and hydrogeological conditions, different SGE solutions can be implemented (Fig. 2).

In cooperation with the Swiss Federal Office of Energy SFOE (SI/501646-01), preliminary evaluation elements for the geothermal potential assessment and the thermal influences of planned tunnel infrastructures for the urban area of Basel (Switzerland) were investigated.

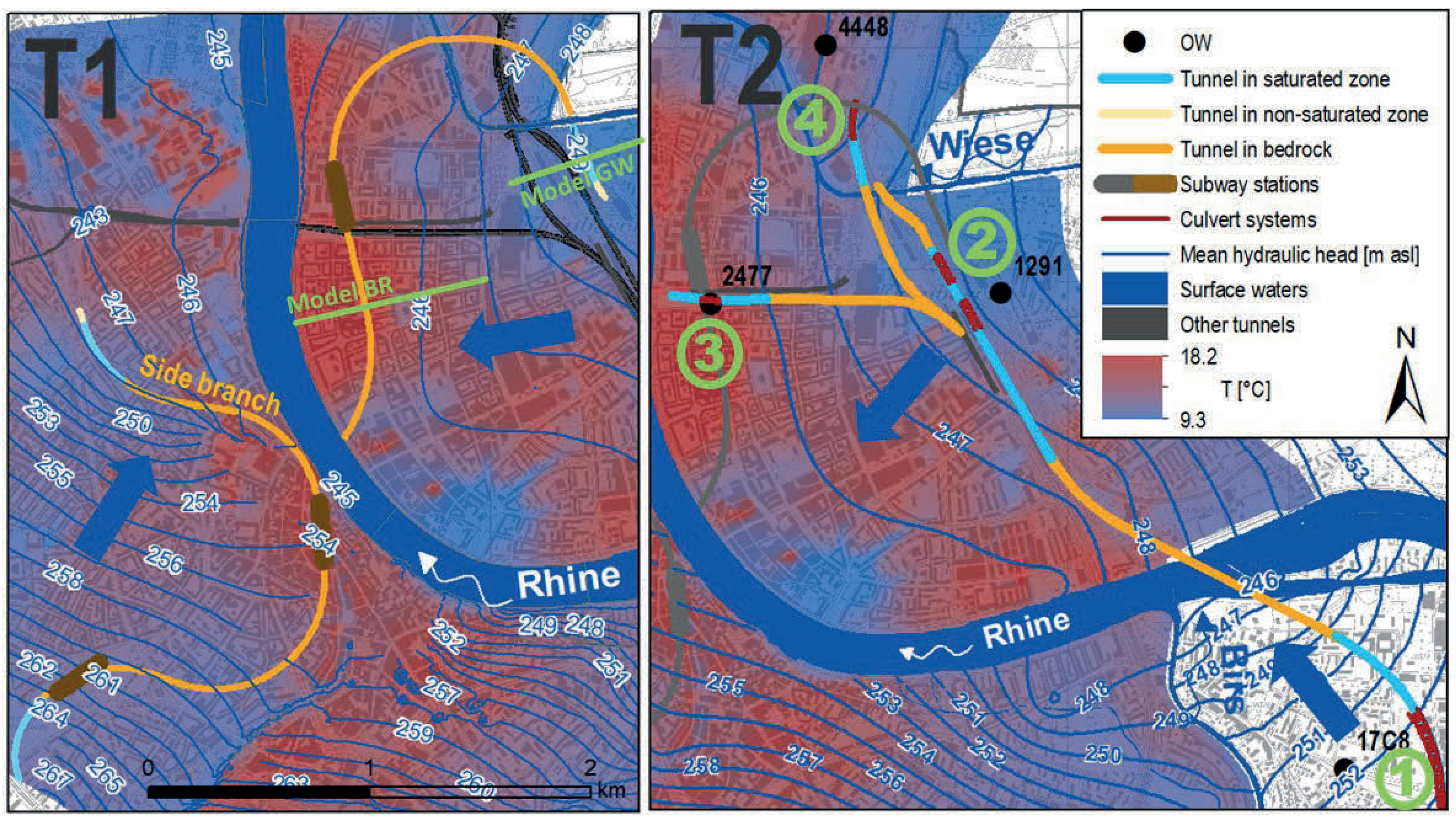


Fig. 2: Sections of planned rail- and motorway tunnels and mean simulated temperature and groundwater flow regime for the years 2010 to 2015.

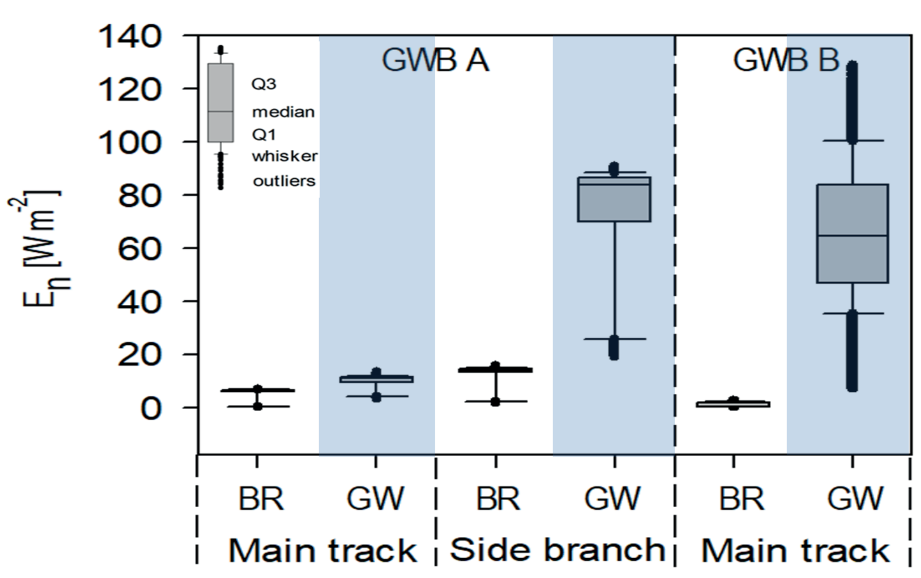
Approach & Methods

City- and local-scale 3D-heat-transport models were set up for evaluating different SGE systems for tunnel infrastructures and determining geothermal potentials of the shallow urban subsurface.

City-scale 3D-heat-transport models allowed deriving total geothermal potentials of SGE system realization in planned infrastructures (Fig. 2).

Local-scale 3D-heat-transport models allowed investigating operational and technical feasibility of TAS in different urban subsurface settings (Fig. 3).

Fig. 4: Heat exchange resulting from the city-scale models standardized to 1 m² of tunnel surface area for the various tunnel sections TS of the planned railway twin tunnel located in the bedrock (BR) and the groundwater-saturated zone (GW, blue shaded) along the main tracks and the side branch of the railway tunnel (Fig. 2).



Tab.: Compilation of total energy yield E_n, seasonal heat exchanged and deliverable thermal energy by heat pumps for the ENERTUN© TAS and SGE systems installed within culverts.

Tunnel Type	Tunnel section GW / BR	E_n [kW] summer	E_n [kW] winter	Seasonal heat exchanged [GWh] summer	Seasonal heat exchanged [GWh] winter	Deliverable thermal energy by heat pump** [GWh] summer	Deliverable thermal energy by heat pump** [GWh] winter
T1 railway twin tunnel	GW	3728.5	1864.3	7.8	3.9	10.4 ('cooling')	5.2 ('heating')
	BR	0.0	980.7	0.0	2.0	0.0	2.7 ('heating')
T1 railway twin tunnel	GW	1366.0	683.0	2.9	1.4	3.8 ('cooling')	1.9 ('heating')
	BR	0.0	760.4	0.0	1.6	0.0	2.1 ('heating')
T2 motorway tunnel	**TS2** GW	62.0	262.5	0.1	0.5	0.2 ('cooling')	0.7 ('heating')
	TS3 GW	7.5	24.5	0.0	0.1	0.0	0.1 ('heating')
	TS4 GW	410.0	761.0	0.9	1.6	1.1 ('heating')	2.1 ('heating')
T2 motorway tunnel	**TS1** GW	168.0	219.0	0.4	0.5	0.5 ('heating')	0.6 ('heating')

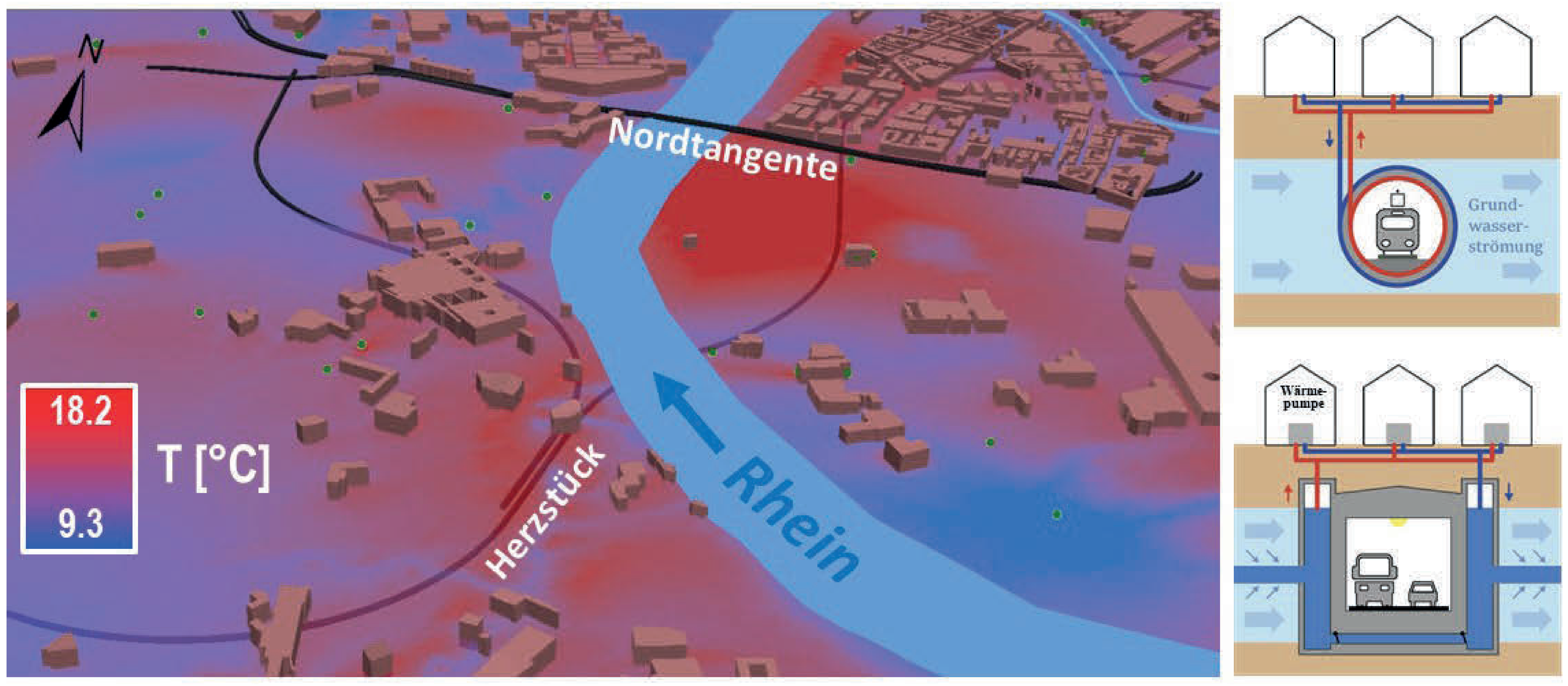


Fig. 1. Left: Groundwater temperatures and urban subsurface constructions, including progression of planned and existent tunnels in the city of Basel, Switzerland. Right: SGE systems in combination with TAS and culvert systems.

Research Subject

'Passive' and 'active' SGE systems have been evaluated, including (Fig. 1 & 2):

- heat-exchange by means of tunnel absorber segments (TAS) for which the thermal activation is achieved by embedding a network of absorber pipes in the structural element (ENERTUN©) where the fluid circulating within the pipes extracts or injects heat from or into the ground.
- thermal exploitation of water circulating in culvert systems which are often necessary as technical measures to enhance groundwater exchange beyond the construction, to avoid backwater effects and the development of stagnating groundwater zones along tunnel infrastructure.

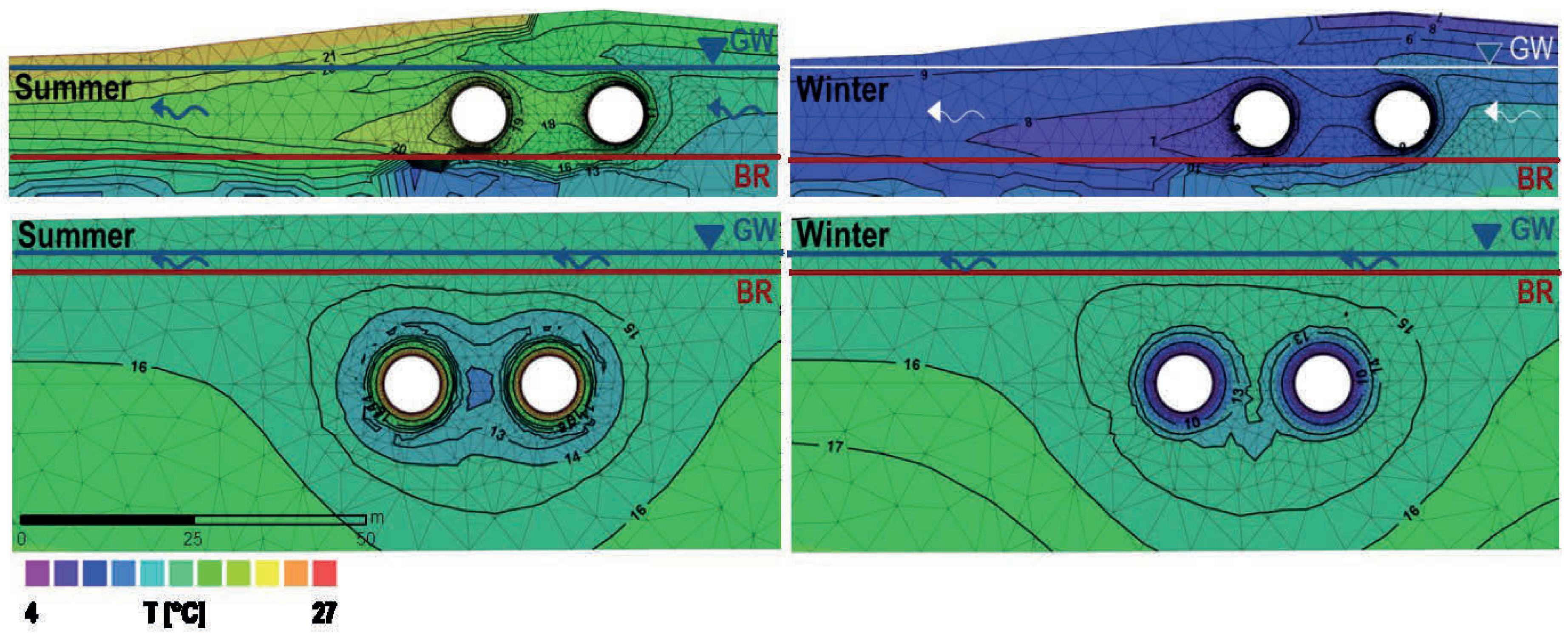


Fig. 3: Temperature distribution of the local-scale models for the thermally activated twin tunnels located completely within the groundwater-saturated zone (GW, above) and in the bedrock (BR, below) as well as for summer (left) and winter (right), respectively.

Results

Thermal activation of a planned railway tunnel is most efficient where it is located within groundwater-saturated zones of the unconsolidated rock deposits.

In summer, thermal power of 3.7 and 1.4 MW can be exchanged from two 736 and 284 m-long tunnel sections (thermal energy of 10.4 and 3.8 GWh for 'cooling', respectively).

In winter, thermal power of 1.9 and 0.7 MW can be exchanged (thermal energy of 5.2 and 1.9 GWh 'heating', respectively).

SGE within culverts reveals to be favorable in heating mode only and for sections where the motorway tunnel runs perpendicular to the regional groundwater flow field where ambient groundwater temperatures are high.

Under such conditions along a 320 m-long tunnel section thermal power of up to 0.4 MW can be provided in summer and 0.8 MW in winter (thermal energy of 1.1 GWh in summer and 2.1 GWh in winter, respectively).

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Reference

Epting J., Baralis M., Künze R., Mueller M.H., Insana A., Barla M., Huggenberger P. (2019): Geothermal Potential of Tunnel Infrastructures – Development of Tools at the City-Scale of Basel, Switzerland. Geothermics, 10.1016/j.geothermics.2019.101734

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