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Toward a conceptual framework of hyporheic exchange across spatial scales

Chiara Magliozzi et al.

Correspondence to: Robert C. Grabowski (r.c.grabowski@cranfield.ac.uk)

Table S1: Collection of worldwide field studies on the hyporheic exchange across a broad range of hydrogeological, topographical and geological settings. Table shows references, geographical zone and state, river name, and information on catchment scale: geology (sediment size and hydraulic conductivity), topographical/morphological, ecological (in-channel vegetation), anthropogenic (agricultural or human infrastructure).

Source	**Hydrological**	**Hydrogeological**	**Topographical**	**Anthropogenic & Ecological**
Angermann et al., 2012	Europe, UK; Atlantic biogeographic region; River Tern; Rainfall: 583 mm / yr	Dominant geology is Permo-Triassic sandstone	/	/
Anibas et al., 2012	Europe;Poland; Continental biogeographic region. Rainfall: 550-700mm/yr, 3 subcatchments	Extensive depression formed during the last glaciations. Unconsolidated aquifers intermixed with confined ones	/	mostly natural but in the low areas of the catchment meadows and pastures
Anibas et al., 2009	Europe; Belgium; Continental biogeographic region	/	/	agricultural landuse and weirs structures
Arntzen et al., 2006	USA; Washington; Columbia Rive; Hanford Reachr; Continental biogeographic region	Miocene to Pliocene of the Ringold Formation, Pleistocene flood gravels of the Hanford Formation	/	/
Bourke et al., 2014	Australia; Subtropical Biogeographic region; Marillana Creek	pisolitic goethite, chert and dolerite	/	mine
Briggs et al., 2010	USA; Massachussets; Ipswich River; humid continental biogeographic region	/	/	three main stem anthropogenic dams
Czernuszenko et. al., 1998	Europe;Moldavia; Botna,Byk and Kogilnik Rivers; Continantal biogeographic region	/	/	/
Datry et al 2008	New Zealand; Selwyn River,Atlantic biogeographic region	confined and semi-confined aquifers	/	/
Dujardin et al 2014	Europe; Belgium; Continental biogeographic region ;Zenne River Rainfall: 852 mm/year	/	/	considerable chemical industrial activity
Duke et al 2007	USA; Texas;Cow Bayou Stream; Humid Subtropical biogeographic region. Rainfall:82 cm/ yr	Eagle Ford shale	/	Dam structure. Agriculture and rangeland Small riparian forest of *Ulmus crassifolia, Fraxinus*

				texensis,Juniperus ashei
Edwardson et al., 2003	USA;Alaska;Kuparuk River; Oceanic-Artic biogeographic region	/	/	/
Fernald et al., 2001	USA; Oregon;Willamette River; Humid-semiarid biogeographic region	Holocene alluvium	/	/
Gooseff et al., 2003	Antartica; Delta Stream and Green Creek; Polar biogeographic region	/	/	/
Haggard *et al.*, 2001	USA; Oklahoma; Dry Creek, Cloud Creek, and Cherokee Creek (Lake Eucha–Spavinaw Basin); humid-subtropical	karstic	/	/
Hall et al., 2002	USA; New Hampshire; 13 Streams; Continantal Biogeographic region	bedrock superficial		forested: *Fagus grandifolia, Acer saccharumBetula alleghaniensis*
Hart et el., 1999	USA; Tennessee; West Fork of Walker Branch; Continental biogeographic region	bedrock outcrops	/	/
Harvey and Fuller, 1998 Harvey *et al*. , 2003	USA; Arizona; Pinal Creek; semi-desert biogeographic region	regional aquifer composed of partially cemented basin fill, a more shallow one is present (sand and gravel). The aquifer presents igneous rock formations and can be constricted	/	/
Jones *et al*. , 2008	USA; Oregon; Umatilla River; humid-semidesertic biogeographic region	Columbia Plateau basalt	naturally anabranched	/
Kasahara *et al.*, 2003	USA; Oregon; Lookout Creek;Humid-semiarid, biogeographic region. Rainfall:2300 -3550 mm/yr	/	/	forested *Psudotsuga menziesii*, Tsuga heterophylla, *Thuja plicata*, A*lnus rubra* and *Salix* spp.

Kasahara *et al.* , 2006	Canada; Ontario; Rouge River tributary 1; Rouge River tributary 2; Silver Creek; Continental biogeographic region	unconfined aquifer	/	/
Kasahara *et al.*, 2007	Canada; Ontario; Boyne River and others; Continental biogeographic region	/	/	/
Kaser *et al.*, 2013	Europe; UK; River Leith; Atlantic biogeographic. Rainfall 900 mm/yr	aeolian Penrith Sandstone	/	/
Knust *et al.*, 2009	USA; Nevada; Truckee River; Desert biogeographic. Rainfall: 18cm/year	/	/	coniferous forests
Krause *et al.*, 2013	Europe; UK; River Tern; Atlantic biogeographic	Permo-Triassic sandstone	/	/
Laenen and Bencala, 2001	USA; Oregon;Willamette River; Humid-semiarid biogeographic	late Pleistocene	/	/
Lamontagne and Cook, 2007	Australia; Swamp Oak creek; Subtropical biogeographic region Rainfall: 670 mm/ yr	/	/	/
Lansdown *et al.*, 2012	Europe; UK; River Leith;Atlantic biogeographic	Permo–Triassic sandstone	/	
Lautz and Siegel, 2006 Lautz and Siegel, 2007	USA; Wyoming; Red Canyon Creek; Semi-arid Intermountain province. Rainfall: 35 cm/yr	Phosphoria Formation. Chugwater Formation. Gravel terraces	/	livestock grazing
Malcolm *et al.*, 2005	Europe; UK; Glen Girnock; Atlantic biogeographic regionRainfall: 1100 mm/yr	schists and gneisses	/	semi-natural heather (*Calluna*) moorland
Malcolm *et al.*, 2010	Europe; UK ; Newmills Burn Girnock Burn; Atlantic biogeographic region	psammite and pelite, granite and schist	/	arable farming and livestook
Malzone *et al.*, 2015	USA; New York State; Elton Creek Continental biogeographic region Rainfall: 760 and 1145mm	Glaciated Appalachian Plateau	/	Land use is primarily forest, dairy, and agriculture with few urban regions
Morrice *et al.*, 1997	USA; New Mexico;Aspen Creek Calaveras GallinaCreek; Semiarid biogeographic region	Permian sandstone and siltstone Bandelier turf granite/gneiss	/	/

Mouw *et al.*, 2009	Alaska; Middle Flathead River Talkeetna River; Artic biogeographic region	/	/	/
Munz *et al.*, 2011	Europe; UK; River Leith; Atlantic biogeographic region Rainfall: 900 mm/yr	Permotriassic Sandstone	/	/
Mutz *et al.*, 2000	Europe; Germany; Schlaube Stream; Continental biogeographic region	/	/	/
Mutz *et al.*, 2003	Europe; Germany; Schlaube Stream; Continental biogeographic region	/		/
O'Connor *et al.*, 2008	USA; California; Elder Creek; Mediterranean biogeographic region	/	/	/
Ock et al., 2015	USA; California; The Trinity River; Mediterranean biogeographic region	/	/	Impounded by the Trinity Dam and the Lewiston Dam since 1964. Flow diverted into the Sacramento River for field irrigation
Pinay *et al.*, 2009	Alaska; Lynx Creek; Artic biogeographic region	/		boreal forest association of white spruce, *Picea glauca*, interspersed with balsam poplar, *Populus balsamifera*
Ruehl *et al.*, 2006	USA; California; Pajaro River; Mediterranean biogeographic region. Rainfall: 33-55 cm/yr	Holocene deposits, the Aromas Formation (Pleistocene), Purisima Formation (Pliocene)	/	agriculture land use
Sawyer *et al.*, 2012	USA; New Mexico; San Antonio Creek; Semiarid biogeographic region Rainfall: 476 mm/yr	/	/	/
Stofleth *et al.* , 2008	USA; Mississippi; Topashaw Creek; Continental biogeographic region	/	/	/
Stonedahl *et al*. , 2012	USA; Indiana; Sugar Creek; Continental biogeographic region	/	/	/
Storey *et al.* , 2003	Canada; Ontario; Speed RiverContinental biogeographic region	primary aquifer is in the dolomite bedrock. The bedrock is overlain by layers of low-permeability	/	/

		glacial till, kame, and outwash deposits		
Swanson *et al.* , 2010	USA; New Mexico; Jaramillo Creek; Semiarid biogeographic region	/	/	/
Thomas *et al.* , 2003	USA; North Carolina; Snake Den Branch; Continental biogeographic region; Rainfall: 200 cm/yr	crystalline rock, schists, gneiss	/	/
Triska *et al.* , 1993	USA; California; Little Lost Man Creek; Continental biogeographic region	/	/	/
Wagenhoff *et al.* , 2014	New Zealand; Kiripaka Stream Whakakai Stream; Atlantic biogeographic region	sedimentary sandstones and siltstones	/	Kiripaka Stream native forest in the headwaters and intensive pasture grazed by sheep and cattle. Whakakai Stream evergreen podocarp- hardwood forest
Wagner *et al.* , 2003	Europe; Austria; Oberer Seebach; Continental biogeographic region	/	/	/
Wondzell *et al.* , 2009	USA; Alaska; Bambi Creek; Artic biogeographic region. Rainfall: 1600 mm/a	/	/	/
Wondzell *et al.* , 2006	USA; Oregon Andrews Experimental Forest; Humid-semiarid biogeographic region	bedrock outcrops	/	/
Wroblicky *et al.* , 1998	USA; New Mexico; Aspen Creek, Rio Calavera; semiarid biogeographic region	Lower Permian fine sandstones and siltstones of the Meseta Blanca Member of the Lower Yeso Formation	/	/
Zarnetske *et al.* , 2011	USA; Oregon; Drift Creek; humid-semiarid biogeographic region. Rainfall: 1190 mm/yr	/	/	agriculture (lower catchment) forestry (upper catchment)

Table S2: Collection of worldwide field studies on the hyporheic exchange across a broad range of hydrogeological, topographical and geological settings. Table shows references, geographical zone and state, river name, and information on valley scale: geology (sediment size and hydraulic conductivity), topographical/morphological, ecological (in-channel vegetation), anthropogenic (agricultural or human infrastructure).

Source	Hydrological	Hydrogeological	Topographical	Ecological	Anthropogenic
Angermann et al., 2012	Mean discharge is 0.9 m3 s-1 with Q95 of 0.4 m3s-1 and Q10 of 1.39 m3 s-1	/	lowland	/	agricultural
Anibas et al., 2012	regular flood event after snowmelt in the upper catchment peatland is mostly groundwtaer fed	The morainic plateau is composed of heterogeneous loamy sand deposits. The flat alluvial valleys are filled with thick deposits of fluvioglacial sand and gravel which are covered by a variety of organic soils.	Lowland mashes and peat lenses (2-5 cm)	oak-beech forests,reed vegetation in the center of the valley and sedges closer to the slope crack	arable lands meandow and pastures in the lower section of the catchment
Anibas et al., 2009	/	/	lowland	/	Agricultural landuse
Arntzen et al., 2006	gaining condition	unconfined aquifer	various topography	/	/
Bourke et al., 2014	losing	/	lowland	/	/
Briggs et al., 2010	/	/	med/low gradient	/	wetland, agricultural land, woodland and urban areas
Czernuszenko et. al., 1998	/	/	lowland	/	/
Datry et al 2008	larger gaining and losing sections of the valley	/		shrubs	/
Dujardin et al	/	/	lowland	/	/

2014					
Duke et al 2007	/	/	/	Riparian forest: *Ulmus crassifolia, Fraxinus texensis,Juniperus ashei*	agriculture, small
Edwardson et al., 2003	/	/	braided, sinuous	*Carex aquatilis* and *Eriophorum vaginatum , Betula nana*	
Haggard *et al.*, 2001	/	shallow silt loams.	/	sycamore trees in Dry Creek and a mix of sycamore trees and other hardwoods in Cloud Creek and Cherokee Creek.	Dry Creek and Cherokee Creek had large grass pastures whereas the up–slope vegetation at Cloud Creek was characterized by underbrush and forest layers
Hall et al., 2002	/	/	medium/low gradient	American beech sugar maple yellow birch	
Hart et el., 1999	/	/	/	deciduous forest	
Harvey and Fuller, 1998 Harvey *et al*. , 2003	/	/	medium/low gradient	tamarisk seedlings, willows	
Jones *et al*. , 2008	/	/	bedrock valley with spring	/	/
Kasahara *et al.*, 2003	/	/	Upland bedrock contrained and unconstrained sections		/
Kasahara *et al.* , 2006	/	/	lowland	grass-vegetated floodplain	residential and agriculture fields

Kasahara *et al.*, 2007	/	/	/	willows along the banks	agricultural (crop and soya beans)
Kaser *et al.*, 2013	gaining	/	meanders within a narrow floodplain (<100)	/	/
Knust *et al.*, 2009	/	/	lowland	coniferous forest	/
Krause *et al.*, 2013	/	/	lowland	/	extensive agricultural land use
Laenen and Bencala, 2001	/	/	Lowland alluvial fans	/	/
Lamontagne and Cook, 2007	/	/		/	/
Lansdown *et al.*, 2012	/	/	lowland	/	agricultural fields
Lautz and Siegel, 2006 Lautz and Siegel, 2007	/	/	upland	/	/
Malcolm *et al.*, 2005	mean discharge of 0.5 m3 s-1, varying between <0.01 m3 s-1 in the summer and >23 m3 s-1 during floods	/	upland	heather (Calluna) moorland	/
Malcolm *et al.*, 2010	/	/	lowland	/	heather moorland, and commercial and semi-natural forest in the lower catchment
Malzone *et al.*, 2015	gaining	/	gaining stream	/	/
Morrice *et al.*, 1997	/	/	upland	/	/

Mouw *et al.*, 2009	/	/	lowland. Large alluvial flood plains	*Populus balsamifera* and shrub communities by *Salix* sp and *Alnus incana* on surfaces flooded. Forested benches are dominated by *P. balsamifera, Picea engelmannii, Pseudotsuga menziesii, Larix occidentalis,Abies lasiocarpa*	cottonwood and spruce forests
Munz *et al.*, 2011	/	/	lowland. narrow floodplain 100m wide. steep slopes with occasional outcrops of the PTS bedrock	grassland vegetation	livestock grazing
Mutz *et al.*, 2000	/	/	lowland. many springs and small streamlets draining from the valley slopes into the stream	/	/
Mutz *et al.*, 2003	/	/	lowland	woodland	/
O'Connor *et al.*, 2008	/	/	lowland	/	/
Pinay *et al.*, 2009	/	/	/	willow *Salix* sp.,moist tundra communities at low elevations; and extensive stands of green alder, *Alnus crispa,* at higher elevations. Little alder is found in riparian areas	/

Ruehl *et al.*, 2006	mean daily discharge 0 and 610 m3/s from 1939 to 2003.	/	lowland	/	/
Sawyer *et al.*, 2012	/	/	lowland, unconfined valley	/	/
Stofleth *et al. ,* 2008	/	/	lowland, straightened (upstream) and channelized (downstream) the chosen reach	/	Little Topashaw Creek: cultivated valley floors and forested hillslopes Goodwin Creek predominately is forest, pasture, and fallow lands
Stonedahl *et al*. , 2012	/	/	Lowland ditched and straightened	/	agricultural fields
Storey *et al.* , 2003	/	/	lowland	/	/
Swanson *et al.* , 2010	/	/	sinuous, with steep stream banks	/	/
Thomas *et al.* , 2003	/	/	steep	mountain laurel (*Kalmia latifolia* L.) and rhododendron (*Rhododendron maximum* L.)	/
Wagenhoff *et al.* , 2014	/	/	upland	/	/
Wagner *et al.* , 2003	/	/	alpine	/	/
Wondzell *et al.* , 2009	/	/	lowland	/	natural
Wondzell *et al.* , 2006	/	/	unconstrained	/	/
Wroblicky *et al.* , 1998	/	/	variable	/	/

Table S3: Collection of worldwide field studies on the hyporheic exchange across a broad range of hydrogeological, topographical and geological settings. Table shows references, geographical zone and state, river name, and information on reach: geology (sediment size and hydraulic conductivity), topographical/morphological, ecological (in-channel vegetation), anthropogenic (agricultural or human infrastructure).

Source	**Hydrological**	**Hydrogeological**	**Topographical**	**Ecological**
Angermann et al., 2012	midsize gravel,different sizes of sand,fine silty materials.	hydraulic conductivities: 10^{-3} to 10^{-5} ms^{-1} and 10^{-8} to 10^{-9} ms^{-1} (Krause et al., 2012)	Meander, pool-riffle- pool bedforms	/
Anibas et al., 2012	loamy sand deposits; thick deposits of fluvioglacial sands and gravels which are covered by a variety of organic soil.	see Table 2 for hydraulic conductivities	meander and straight section steep banks	banks mostly are covered with reed plants.
Anibas et al., 2009	fine sand and some organic material	thermal conductivity: 1.8 Js^{-1} m^{-1} K^{-1}	straight and canalized	/
Arntzen et al., 2006	cobble (>64 to<=128mm) in a matrix of fine sand (>0.062 to<=0.5mm). At rkm 602 site, the median grain size—D50 was 57.7mm. At rkm 582 site, the dominant substrate was coarse gravel (>16 to<=64mm) in a matrix consisting mostly of fine sand (>0.062 to <-=0.5 mm). The D50 at rkm 582 was 35.5mm. At rkm 577, the dominant substrate was coarse gravel (>16 to <=64mm) in a matrix consisting of fine sand. However, there was a silt component at rkm 577 much larger than at the other two locations. The D50 at rkm 577 was 22.3mm.	hydraulic conductivities: 8.8x10^{-3} cms^{-1} to 2.9x10^{-4} cms^{-1}	/	/
Bourke et al., 2014	/	hydraulic conductivity1500 and 3700md^{-1}	straight, section with pools, riffles and glides bedforms	/
Briggs et al., 2010	hallow soils and glacial deposits	/	meander section	beaver activity and wood dams

Czernuszenko et. al., 1998	/	/	Straight Low sinuosity	/
Datry et al 2008	gravels, cobbles,and small boulders	/	riffles, prafluvial bars, terraces	annual grasses and herbs
Dujardin et al 2014	silty and clay- loam	hydraulic conductivities see Table 2	/	/
Duke et al 2007	clay-rich vertisol	0.104 cm h^{-1}	/	*J. ashei*
Edwardson et al., 2003	cobble, gravel,peat but variable according to site	hydraulic conductivities: see Table 3	pool riffles, meanders,Debris dam	/
Fernald et al., 2001	gravel Holocene deposit	10^{-2} and 10^{-1} m s^{-1}	two large island complexes with anastomosing channels and extensive exposed gravels.	/
Gooseff et al., 2003	very porous	/	/	/
Haggard *et al.*, 2001	cobbles with some fines	/	/	/
Hall et al., 2002	cobbles and boulders	/	debris dams	/
Hart et el., 1999	gravel and cobbles, bedrock outcrops	/	boulders and debris dams are	imput of deciduous forest: leaves
Harvey and Fuller, 1998, Harvey *et al*. , 2003	sand and gravel	/	straight section cobbles and channel parallel bars at side and central channel	/
Jones *et al*. , 2008	basalt gravel, cobbles, and boulders intermixed with silt and sand lenses	300 to 700 m day^{-1}	naturally anabranched	in-channel macrophytes vegetation (season dependent)
Kasahara *et al.*, 2003	coarse-textured gravel	/	/	/

Kasahara *et al.* , 2006	cobbles	<0.1m day^{-1} to >10 m day^{-1}	riffles and step from restoration project	/
Kasahara *et al.*, 2007	gravel bed channel,silt and clay	0.3 to >20m day^{-1}	gravel bar and menader bends were selected for studying	
Kaser *et al.*, 2013	soft sediment	2.7–2.8x10^{-5} ms^{-1}	Meander riffle-pool sequences	/
Knust *et al.*, 2009	cobbles and boulders	/	straighter and wider	/
Krause *et al.*, 2013	Midsize gravel, Different sizes of sand Fine silty materials	hydraulic conductivities 10^{-3} to 10^{-5} ms^{-1}	meandering section steep river banks, pool-riffle-pool sequences	/
Laenen and Bencala, 2001	sands, silts, and clays	/	meandering and braided channel with many islands and sloughs.	/
Lamontagne and Cook, 2007	coarse sand, gravel, and cobble	porosity of ~0.4	/	/
Lansdown *et al.*, 2012	sand, gravel, and cobbles on sands and silts	/	riffle and pool sequences	/
Lautz and Siegel, 2006, Lautz and Siegel, 2007	gravel and fine sand but also silt	hydraulic conductivity see Table 1 Lautz and Siegel 2006	meandering and straight sections	debris dams and small log dams (natural and non)
Malcolm *et al.*, 2005	Podzols, gleys and peats	/	/	/
Malcolm *et al.*, 2010	overlain by glacial till and meltwater deposits and overlain by glacial and fluvioglacial deposits.	/	deepened and straightened pool riffles,bars	/
Malzone *et al.*, 2015	sand, gravel, clay, and till	/	pool and riffles sequences	/

Morrice *et al.*, 1997	2%gravel 46%sand 42%silt 10%clay 36%gravel 53%sand 9%silt 2%clay boulders cobbles gravel and sand	/	/	/
Mouw *et al.*, 2009	gravel to sand	/	anastomosing channels pools	/
Munz *et al.*, 2011	silt to coarse sand	/	meandering section of the river. Longitudinal pool-riffle-pool sequence	riparian reed and grass vegetation. wet grassland and sparse riparian soft-wood vegetation alongside
Mutz *et al.*, 2000	Fine/ medium sand with some gravel	/	sinuous	*Alnus glutinosa* and *Carpinus petulus.* In-channel wood.
Mutz *et al.*, 2003	coarse to fine sands	/	/	/
O'Connor *et al.*, 2008	boulders	/	riffle-pool. slope of 0.026. sinuosity ratio of 1.1	/
Ock et al., 2015	coarse gravel	/	4 channel-gravel features (bars and vegetated islands)	/
Pinay *et al.*, 2009	gravel	$2x10^{-4}$ and $3x10^{-3}$ cms^{-1}	/	/
Ruehl *et al.*, 2006	/		/	/
Sawyer *et al.*, 2012	Mix cobbles, gravel on silt	4.0 m d^{-1}	two straight runs separated by a meander. Pool and riffle sequences	grasses and forbs.
Stofleth *et al.* , 2008	silt and clay soils over sand	/	tortuous reach section mild channel slope	/
Stonedahl *et al*. , 2012	gravel, pebble, and coarse sandy glacial	/	pools and riffles	/

Storey *et al.* , 2003	recent alluvium	2 x 10^{-4} ms^{-1}	/	/
Swanson *et al.* , 2010	sand and gravel	3.2x10^{-5}	losing condition of the reach and pool-riffle- pool sequence	banks stabilized by dense communities of grasses
Thomas *et al.* , 2003	colluvial sediments coarse material	/	steep colluvial sections	large oak-hickory stands with cove hardwoods common along the stream channel
Triska *et al.* , 1993	gravel	/	/	/
Wagenhoff *et al.* , 2014	gravels and sand	/	wood logs in both streams	/
Wagner *et al.* , 2003	gravel to fine	/	steep slope in the upstream section. Downstream section characterized by wetland area between the hill and the left bank	Riparian vegetation: *Salix caprea L., Salix myrsinifolia Picea abies L., Fraxinus excelsior L., Acer pseudoplatanus L., Fagus sylvatica L. and Corylus avellana L. Also present but less abundant are Acer platanoides L., Alnus incana Cornus sanguinea L.* and *Crataegus monogyna*
Wondzell *et al.* , 2009	fine gravel to sand	/	low gradient	/
Wondzell *et al.* , 2006	boulders, cobbles, gravels and finer textured sediment	9.2 m day^{-1}	steep channels	wood debris
Wroblicky *et al.* , 1998	poorly sorted, gravelly, coarse sand with occasional cobbles and boulders.	see Table 2 for hydraulic conductivities	/	/
Zarnetske *et al.* , 2011	sand, gravel, cobbles, and boulders.	/	planebed and riffles0.007 m m−1 (reach slope)	/