The Influence of Gravel Bars on Urban Water Quality, NE Branch of the Anacostia River

Patrick Deery; Advisor: Dr. Karen Prestegaard, University of Maryland

Background Information

- Urban river systems are often subject to increased flow velocity, temperatures and sediment loads.
- The Northeast Branch of the Anacostia demonstrates limited sediment loads at low flow, temperatures within acceptable ranges for sensitive species and well regulated flow through its' numerous channels despite being host to numerous sources of anthropogenic change.
- Hwang & Foster, 2006 found significantly elevated of Polycyclic Aromatic Hydrocarbons (PAHs) and Heavy metals associated with elevated storm discharge from urbanized reaches of the Anacostia.
- Ock *et al,* 2011 found gravel bars play a significant role in mitigating the effects of anthropogenic change in their study of restored gravel bars in the Trinity River, California.

Hypotheses

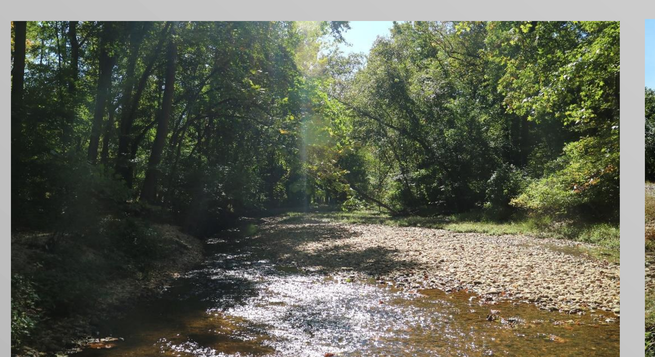
1. Gravel Bars serve to regulate temperature through exchange of stream water with groundwater in the bars.
2. Gravel bars improve water quality by trapping and storing fine sediment (sand sized and smaller). The total amount of sand-sixed and smaller sediment is significantly higher in gravel bars, than in adjacent channels.
3. Gravel bars improve water quality by trapping particulate organic carbon. Particulate organic carbon can sorb organic contaminants and trace metals, reducing their concentrations in stream water.

Study Sites

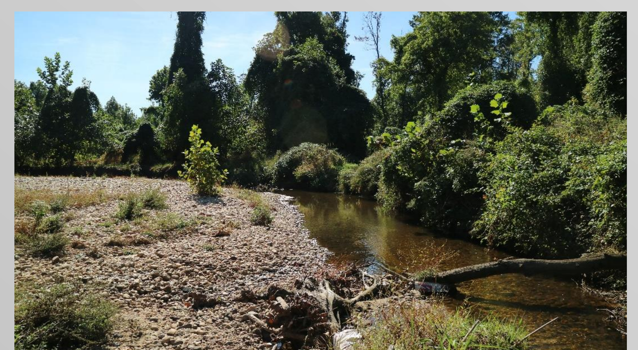
- This study focuses on a series of three gravel bars present along two urbanized channels of the Northeast Branch of the Anacostia, Paint Branch Creek and Little Paint Branch Creek.

Bar Characteristics

Gravel Bar	Bar Type	Length (m)	Average Width (m)	Bar Area (m^2)
Bar One	Alternate	61.6	9.8	595
Bar Two	Point	35.2	33.7	1783
Bar Three	Alternate	80	35	2800



Bar One, LPBC



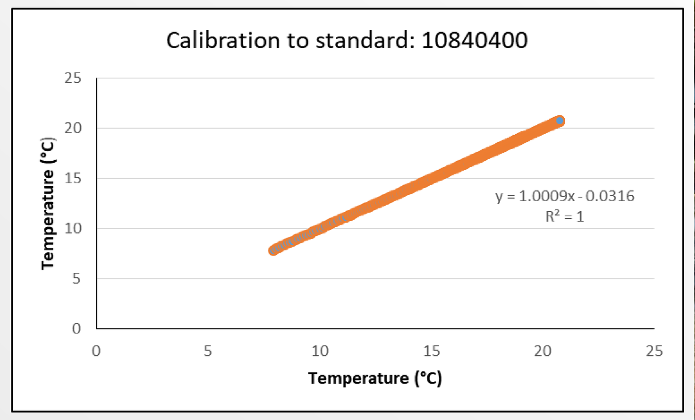
Bar Two, LPBC

Bar Three, PBC

All photos by Patrick Deery, unless otherwise specified

Methods: Temperature

- Stream water temperature was measured with pairs of in-situ temperature sensors, placed upstream and downstream of 3 gravel bars along Little Paint Branch Creek and Paint Branch Creek.
- The sensors (Onset HOBO Tidbit v2's) recorded instantaneous temperature data at two minute intervals.
- Sensors were calibrated to a non-field use standard to improve the accuracy of the temperature analysis.

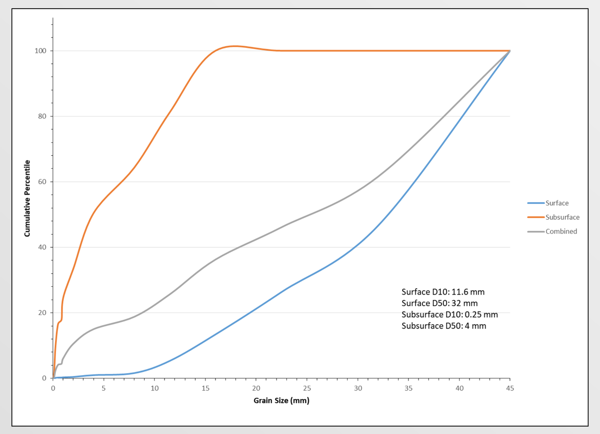


Onset HOBO Tidbit v2

Methods: Grain Size Analyses

- Sediment samples were collected from the surface and subsurface of the bars along Little Paint Branch Creek. (Approx. 50 samples in total)
- These samples were dried and sieved to half phi intervals.
- Cumulative probability graphs were constructed to obtain median (D_{50}) and D_{10} sizes.
- Fine sediment fractions (< .125 mm) were than split, into 3 samples, weighed and prepared for Loss on Ignition (LOI) analyses.
- In-situ slug tests were conducted to determine hydraulic conductivity and residence time.

Sediment Sampling, Bar Two, LPBC

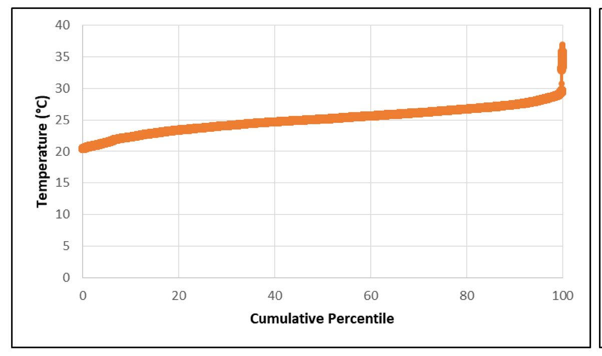


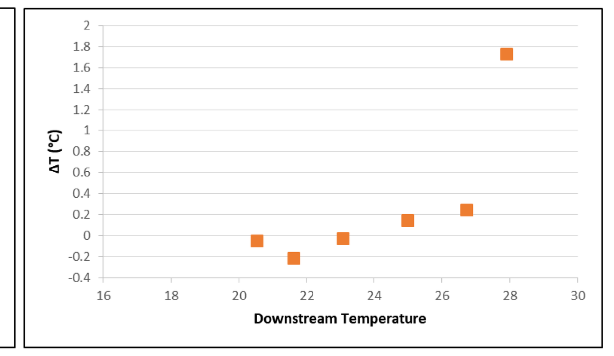
Cumulative Grain Size Distribution, Bar One, Mid

Methods: Organic Material

- Fine sediment samples previously separated during the sieve analyses were moved to crucibles.
- Samples were then weighed and placed in a muffle furnace at 550°C for 3 hours.
- After the bake period samples are allowed to cool for several hours, and are then reweighed, and mass LOI was calculated.

Results: Temperature





Bar One

Percentile	UP	DOWN	ΔT
min	20.674	20.793	-0.119
5th	22.393	22.298	0.095
16th	23.376	23.256	0.12
median	**25.089**	**24.653**	**0.436**
84th	26.891	26.182	0.709
95th	27.899	27.161	0.738
max	29.74	28.394	1.346
Mean	**25.1**	**24.681**	0.419
Std. dev.	1.681	1.458	0.223

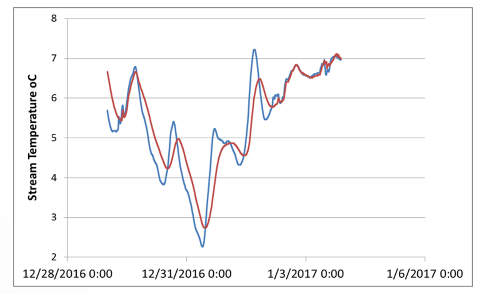
Bar Two

Pectentile	UP	DOWN	ΔT
min	20.484	20.531	-0.047
5th	21.413	21.628	-0.215
16th	23.064	23.064	-0.024
median	**25.137**	**24.992**	**0.145**
84th	26.965	26.72	0.245
95th	28.072	27.899	1.73
max	35.823	36.96	-1.137
Mean	**25.851**	**25.971**	0.100
Std. dev.	5.202	5.521	0.851

Bar Three

Percentile	UP	DOWN	ΔT
min	21.127	21.175	-0.048
5th	23.905	23.448	0.0358
16th	24.074	24.895	0.457
50th	**26.304**	**25.671**	**0.633**
84th	28.692	25.914	2.778
95th	30.016	27.21	2.806
max	32.073	30.52	1.553
Mean	**26.599**	**25.548**	1.174
Std. Dev	3.866	2.932	1.223

- Cumulative probability analyses indicate that the temperature change (ΔT) (Upstream –Downstream) increased with stream water temperature.



- Data from November 2016 to January 2017 indicate groundwater mixing: floodplain GW mixed in gravel bars increases minimum temperatures and decreases maximum temperatures.

Results: Grain Size Analyses

- Grain size analyses indicated significant levels of <2mm grains present in subsurface of gravel bars along LPBC often on the order of 15% total subsurface sample mass. (15% of total sediment mass)
- Analyses similarly revealed low levels of fine (<0.125mm) sediment storage, typically less than 2% total sample mass.
- In-situ analysis of hydraulic conductivity indicated that groundwater flow through gravel bars is controlled by subsurface (D_{10}) grain size.

Bar One: Subsurface

Grain Size	(B1, US, S1)	(B1, US, SS1)
<0.063	0	0.086
0.063	0.012	0.164
0.125	0.041	1.039
0.25	0.187	6.831
0.5	0.041	13.836
0.85	0.362	15.802
1	0.567	25.029
2	0.743	35.05
4	1.106	47.841
8	1.609	55.716
11.5	5.242	67.03
16	19.232	81.749
22.5	27.739	97.188
32	44.448	99.804
45	100	99.804

Gravel Bar Residence Time

Bar	Darcy Velocity (m/s)	Velocity (m/s)	Residence Time (hrs)
Bar One	0.0001	0.0002	90.0585
Bar Two	0.0002	0.0008	11.9679
Bar Three	0.00005	0.0002	133.6675

Results: Organic Material

- Loss on Ignition analyses yielded small percentages (1.9%-5.1%) of organic matter within the fine sediment fraction of subsurface sediment samples.

LPBC Sample ID	Sample & Cruicble Wt (preburn) (g)	Sample Wt (Pre burn) (g)	Post Burn Wt (g)	Mass LOI (g)	% Mass LOI
Bar One Upstream One:	14.660	2.579	2.479	0.100	3.882
Bar One Upstream Two:	25.243	13.000	12.873	0.128	1.925
Bar One Upstream Three:	22.354	9.174	8.825	0.349	1.924
Bar One Middle:	15.556	3.388	3.138	0.250	3.763
Bar One Downstream:	19.757	7.242	7.066	0.177	4.815

LPBC Sample ID	Sample & Cruicble Wt (preburn) (g)	Sample Wt (Pre burn) (g)	Post Burn Wt (g)	Mass LOI (g)	% Mass LOI
Bar Two Upstream One:	20.593	7.413	20.305	0.287	3.877
Bar Two Upstream Two:	24.669	12.154	24.204	0.464	3.820
Bar Two Upstream Three:	15.018	2.850	14.872	0.146	5.120
Bar Two Middle:	14.304	3.294	14.174	0.130	3.950
Bar Two Downstream One:	22.006	9.763	21.771	0.235	2.404
Bar Two Downstream Two:	17.188	5.106	16.976	0.212	4.152

Discussion

- Analyses of temperature data suggests that gravel bars reduce stream temperature during summer months.
- During cooler months, data suggest mixing of stream water with a major source of constant temperature water (likely floodplain groundwater).
- Sand-sized sediment is stored in gravel bars, but silt and clay sized sediment is not stored in major quantities, but bars can enhance overbank flows and floodplain storage (Blanchet, 2009).
- Organic matter fractions present in sediment samples ranged from (0.001% to 0.0016%). This meets or exceeds levels present in previous studies of fluvial materials that retain large quantities of anthropogenic contaminants (Roberts *et al*, 1986).

Conclusions

1. Analyses of stream water temperatures upstream and downstream of gravel bars support the hypothesis that gravel bars reduce summer peak temperatures.
2. Grain size analyses revealed little fine (<0.125 um), but up to 15% < 2 mm sediment, suggesting gravel bars do not act to retain significant quantities of the silt and clay fractions often considered contaminants.
3. Organic Matter analyses indicated that the total fraction of organic matter is small (0.001 to 0.0016), but this is a larger fraction of the total sediment than observed in previous studies of alluvial sediments that sorb significant quantities of organic contaminants.

Implications

- Organic material can sorb and retain Heavy Metals and PAH's harmful to people and local biota.
- Analysis of Heavy Metal partition coefficients around bar two, suggests that gravel bars can serve as sites significant sorption for anthropogenically derived Cd, Pb and Zn.

example: $K_d' = K_d oc * f_{oc}$

Gravel Bar Sediment & OM Fraction (%)				
Gravel Bar	f Sand	f Silt	f Clay	f OC
Bar two	0.2028	0.0282	0.0277	0.00012

Partition coefficients metals common in stormwater				
Contaminant	Kd sand	Kd silt	Kd Clay	Kd oc
Cadmium, Cd	1,900	9,600	8,400	112,000
Lead, Pb	270	16,000	550	22,000
Zinc, Zn	200	1,300	2,400	1,600

Effective Kd (L/Kg)				
	Kd' sand	Kd" silt	Kd' clay	Kd' oc
Cd	385.32	270.72	232.68	13.44
Pb	54.756	451.2	15.235	2.64
Zn	40.56	36.66	66.48	0.192

Downstream of bar two

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