Water Resources Center
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Introduction

Three research projects were completed. The research projects investigated the treatment of roadway runoff using crushed concrete, bioremediation of contaminated soils and baseline monitoring of contaminants in a regional watershed. The technical transfer project set up a RI Water Resources Center Website to allow easy access to the Center's technical reports.

Research Program

Treatment of Roadway Runoff

Basic Information

Title:	Treatment of Roadway Runoff
Project Number:	2001RI1801B
Start Date:	3/1/2001
End Date:	4/30/2002
Funding Source:	104B
Congressional District:	2nd
Research Category:	Water Quality
Focus Category:	Treatment, Water Quality, Waste Water
Descriptors:	stormwater treatment, roadway runoff, adsorption, precipitation
Principal Investigators:	Leon T Thiem

Publication

1 INTRODUCTION

Many of the current stormwater runoff Best Management Practices (BMPs) are too land intensive to be easily implemented in an urbanized setting. Smaller physical treatment devices, such as oil/sediment separators, that have been widely installed in urbanized areas have been shown not to be efficient enough in removing dissolved contaminants and very fine particulates from the runoff. This is a particular problem with trace metals, most of which are either dissolved or adsorbed to these very fine particulates.

To solve the problem of reducing the trace metal concentration in urbanized stormwater and roadway runoff, researchers in the Department of Civil and Environmental Engineering at the University of Rhode Island have been conducting research on the development of a low-maintenance filtration system designed to be used downstream of an oil/sediment separator. This filtration system will remove not only large particulates but also the dissolved fractions of metals associated with urbanized runoff. The uses of various media for this filter, such as activated carbon and crushed concrete have been explored.

1.1 Objective of Study

The goal of this investigation was to analyze filter media/absorption combinations to optimize the removal of non-settleable trace metals from simulated urban roadway runoff. Using a bench-scale apparatus, influent water spiked with the six trace metals found in Rhode Island roadway runoff that exceeded the EPA National Recommended Water Quality Criteria was pumped through beds of Granular Activated Carbon (GAC)

and Crushed Concrete at a constant loading. Three separate crushed concrete bed depths were first analyzed to determine an optimal bed depth of the concrete media. After this crushed concrete bed depth was determined, one experimental run with both GAC and crushed concrete media took place to determine how much the GAC affected the pH and trace metal concentration of the water before it entered the crushed concrete media. The results found in this study will eventually be incorporated into developing a treatment process to be added downstream of oil/sediment separators that are currently in use in many urbanized areas.

2 BACKGROUND

The Rhode Island roadway runoff characterization report conducted in 1999 confirmed the presence of trace metals in the highway runoff in Rhode Island and provided concentrations for both winter and non-winter conditions. The study found that cadmium, chromium, copper, lead, nickel, and zinc exceeded the National Recommended Water Quality Criteria (Thiem, Bade, and Alkhatib, 1999). These criteria are specified for both freshwater and saltwater bodies, and are reported as the Criterion Maximum Concentration (CMC) and Criterion Continuous Concentration (CCC). The CMC is an estimate of the highest concentration of a contaminant which aquatic life can be exposed to for a short time; the CCC is an estimate of the highest concentration of a contaminant to which aquatic life may be exposed indefinitely (USEPA, 1999). Table 2.1 lists the National Recommended Water Quality criteria of the various contaminants of interest in this study, the range of concentrations found in the Rhode Island roadway runoff characterization report conducted by Thiem et al., and the average concentrations of the trace metals used in this study.

2.1   Metals in Urban and Roadway Stormwater Runoff

Metals found in stormwater runoff make up one of the more permanent contaminants in the environment. In 1998, metals were found to be the second leading pollutant of lakes, reservoirs and ponds in the U.S., and the third leading pollutant of estuaries (USEPA, 2000). Metals are elements, and unlike many pollutants, they cannot be broken down by chemical or biological processes. Since they do not degrade with time, metals may build up in the bottom sediment of water bodies over long periods and gradually enter the food chain.

Trace metals are primarily a concern in stormwater runoff because of their detrimental effects on aquatic life and their potential to contaminate drinking water supplies. Trace metals may be found in natural waters in particulate form by the formation of precipitates, such as hydroxides, sulfides, and carbonates, or by adsorption to clay, silica, or organic particulate matter (Gannon, Bartenhagen and Hargrove, 2001).

A recent study on the constituents in roadway runoff in Rhode Island analyzed the relationships between the constituent concentrations, total suspended solids (TSS), and conductivity. If a constituent had a high degree of correlation with TSS, it indicated that the constituent was present in the particulate form or was adsorbed to particulates in the runoff. If a constituent had a high degree of correlation with conductivity, the constituent was present in dissolved form. The study concluded that cadmium and lead were associated with the particulate fraction in the runoff, nickel was present in dissolved form, and that chromium, copper, and zinc were present in both dissolved and particulate form (Thiem et al., 1998).

2.2   Physical and Chemical Removal Techniques

A large fraction of heavy metals in stormwater runoff adhere to very fine particles of sediment and are subsequently transported with those sediments by the stormwater. Since most contaminants have a strong attraction to suspended solids, the removal of TSS will very often simultaneously eliminate many trace metals from urban stormwater.

In a 1999 study done by Kueddelsmann, a comparison of filtration sand and a GAC/crushed concrete media was analyzed. The filter combination of GAC and concrete removed almost all dissolved trace metals to concentrations below EPA water quality criteria. The filtration sand, however, did not have as high a removal rate for trace metals as did the GAC and crushed concrete combination. It was concluded that the combination of GAC and concrete worked well together because each layer contributed a unique removal mechanism. The dissolved contaminants in the water attaches to the surface of the GAC (adsorption) whereas the concrete causes the soluble contaminants to precipitate due to the change in pH (Kueddelsmann, 1999). However, because of the broad scope of the study, the combination of using GAC and crushed concrete as filtration media was not under much scrutiny. The concrete used by Kueddelsmann was of unknown age and composition, and only approximately 10 empty bed volumes of water were treated by the GAC/Crushed Concrete media. Therefore, additional studies were undertaken to analyze this filtration combination.

In a 2001 study carried out by Robbins, the relative abilities of four combinations of crushed concrete filtration media were compared. The mixtures were hydrated combinations of Portland cement with added high-calcium hydrated lime and/or fine sand

aggregate. It was found that the use of crushed concrete as a filtration medium is a viable method of raising the pH of acidic stormwater runoff over an extended period of time. The addition of hydrated lime, which is commonly used in cement-lime mortars, did not improve the long-term use of the media, and actually appeared to be detrimental. In addition, it was found that there was no significant advantage to omitting the fine aggregate. Therefore it was concluded that the use of an aggregate-containing concrete was effective for treating the runoff (Robbins, 2001).

Based on the results of the past two studies, the promising methods of successfully removing trace metals from urban roadway runoff with adsorption by granular activated carbon and by precipitation using crushed concrete were further analyzed in this study. Aggregate-containing concrete bed depths of 1.5, 3, and 6-inches were analyzed for their removal capacities of trace metals concentrations typically found in Rhode Island roadway runoff. An optimal bed depth was determined based on relationships analyzing the effluent pH, number of bed volumes treated, cumulative mass removed of each particular metal, and metal removal percentages. Once an optimal concrete bed depth was determined, a packed GAC column of the same thickness was placed before the crushed concrete media and both media were analyzed together for their combined removal capacity of the metals.

2.2.1   Carbon Adsorption

In full-scale water treatment by adsorption, activated carbon is used almost exclusively. Activated Carbon is an adsorbent derived from carbonaceous raw materials. Through an "activation process" in which thermal or chemical means have been used to

remove most of the volatile non-carbon constituents and a portion of the original carbon content from the material, a structure results with a high surface area ideal for adsorbing a wide range of compounds. The resulting carbon particles have thousands of small pores, which make it an ideal adsorption material.

Granular activated carbon (GAC) has shown the potential for adsorption of trace metals that are present in dissolved and particulate form in water. For the metals of interest in this study, chromium has been shown to have high adsorption potential, lead and nickel to have fair adsorption potential, and copper, cadmium, and zinc to have low adsorption potential (Montgomery, 1985).

2.2.2 *Chemical Precipitation*

Another method of removing the non-settleable trace metals found in urban runoff is by chemical precipitation of the metals to form insoluble species. Filtration then can easily remove the resulting precipitates. The most prevalent means of metal precipitation is the formation of insoluble hydroxides, which can be accomplished by merely increasing the pH of the water to be treated.

To achieve chemical precipitation of metals from the runoff, the contaminated water can be passed through crushed concrete to raise the pH. As previously stated, Robbins' research at the University of Rhode Island showed that the use of crushed concrete as a filtration medium was a practical method of raising the pH of acidic stormwater runoff over an extended period of time (Robbins, 2001).

The concrete media serves as a source of hydroxide ions. These ions are transferred from the media to the treated water, thereby increasing the pH of the treated

water. The source of these hydroxide ions comes from the formation of calcium hydroxide in fully hydrated cement. When Portland cement contacts water, a series of chemical reactions occur. Calcium hydroxide (25%) and calcium silicate (50%) make up the two major constituents present in the resulting fully hydrated cement (Kosmatka and Panarese, 1994).

Few studies have been done regarding the long-term ability of crushed concrete to raise the pH of influent water. One study was carried out by the Minnesota Department of Transportation, where they analyzed the pH of effluent water leaching from stockpiles of salvaged crushed concrete of unknown age during precipitation events. Over the course of the 14 month monitoring period, the effluent pH decreased from slightly greater than 10 to slightly greater than 9, with the median effluent pH for the coarse concrete being 9.8, and 9.3 for the fine concrete. The study also stated that these values were above the national recommended water quality criteria for pH, which are 6.5 to 9 for freshwater, and 6.5 to 8.5 for saltwater (USEPA, 1999). The study found that the resulting increased pH would not be a problem because naturally acidic untreated rainwater and runoff would tend to neutralize the alkalinity of the stockpile effluent (Sadecki, et.al., 1996).

Two recent studies were done at the University of Rhode Island analyzing the use of concrete to raise the pH of influent water. In Kueddelsmann's study (1999), the highest effluent pH observed from the concrete was slightly less than 11.5. In Robbins' study (2001), the *lowest* effluent pH observed was slightly above 11, with the highest effluent pH of about 12.3. The lower pH in Kueddelsmann's study may perhaps have been due to the fact that freshly made concrete was not used in her study, resulting with calcium

hydroxide reacting with atmospheric carbon dioxide. This may also explain the lower effluent pH values seen from the stockpiles of salvaged crushed concrete of unknown age in the Minnesota DOT study. In addition, the crushed concrete was backwashed for several hours prior to each of her experimental runs, thus flushing out the hydroxide ions that may have also caused an initially lower effluent pH. The particle size of the concrete may too have been an issue. Kueddelsmann used a uniform U.S. Standard #4 sieve size for her crushed concrete whereas Robbins used a 16x40 sieve size. The smaller concrete particle size had a larger surface area and may in turn raise the effluent pH higher than the larger concrete particle size.

Kueddelsmann's research also showed a correlation between increasing pH (within the range of pH 7 to 11.5) and percent removal of several trace metals, including cadmium, copper, lead and zinc. The exception to this trend was chromium, for which the removal rate declined at pH values exceeding 10.5 (Kueddelsmann, 1999). The study agreed with values stated in literature that the solubility of many heavy metals is lowest within the range of pH 7-11.5. The solubility of nickel, copper (II), lead (II), and zinc (II) hydroxide is lowest in the range of pH 9-11 with cadmium hydroxide typically lowest for pH values ranging from about 10.5 to 12.5 (Manahan, 2000).

4.2.1 Discussion

The purpose of this part of the experiment was to determine if the GAC would have an effect on the metal removal of the influent water before it is to pass through the crushed concrete column. It was first found that virgin GAC does affect the pH of the water. The water after passing through the GAC had an initial pH of about 10.8, however the pH quickly dropped in the first hour of the run to 8.5 and towards the end of the run

the GAC effluent pH was approximately equal to the influent pH (approximately 5.0). This is likely the reason why there was significant removal of the metals in the GAC earlier in the filter run and not later on when the effluent pH of the GAC was lower. Cadmium, lead and nickel show the highest removal in the GAC at the beginning of the filtration run (when the pH was highest). Copper and zinc show the highest removal in the GAC in the pH range of 8.5-9.0. The pH that exhibited highest removal of the individual trace metals also corresponds to the lowest solubility of the metals. Chromium (VI) shows the highest removal in the GAC around a pH of 6.0. For all metals analyzed, the only significant trace metal removal in the GAC was with chromium, where around 70% removal was typically achieved. The crushed concrete column achieved removal of all other metals. With the combination of GAC and crushed concrete, all six metals analyzed received significant removal in the dual media filter, which is summarized in Table 4.3. Table 4.3 also lists the EPA's Freshwater and Saltwater Criterion Maximum Concentrations of the National Recommended Water Quality Criteria, which were also shown in Table 2.1. The Freshwater and Saltwater CMC's are shown here for comparison with the average final concentrations achieved through the filtration of the dual media. Although the average final concentrations are considerably less than the average initial concentrations, all with the exception of nickel are still not below the Criterion Maximum Concentrations. However, it needs to be emphasized that the concentrations used in this study were based on the extreme trace metal concentrations that were found in roadway runoff.

Contaminants	Average Initial Concentration (µg/L)	Average Total Removal in Dual Filter	Average Final Concentration (µg/L)	Freshwater CMC (µg/L)	Saltwater CMC (µg/L)
Cadmium	18.6	70%	5.58	1	40
Chromium (VI)	67.4	68%	21.6	16	--
Copper	212	45%	117	13	4.8
Lead	66.3	75%	16.6	65	210
Nickel	90.1	67%	29.7	470	74
Zinc	1067	53%	501	120	90

Table 4.3   Summary of Metal Removal in Dual Column

Table 4.4 shows a comparison of the range of pH values that depict the lowest solubility values of the metals of interest along with the pH ranges that had the highest metal removal in this study. Generally, the pH range that had the highest metal removal also corresponded to the pH range that had the lowest solubility of that metal.

Contaminants	Lowest Solubility Range (Metcalf & Eddy, 2002)[1]	pH Range of Highest Removal
Cadmium	10.5-12.5	10.5-11.5
Chromium (VI)	<7.0	5.0-6.5
Copper	8.0-10.5	8.0-11.5
Lead	8.5-10.5	10.5-11.5
Nickel	8.5-11	10.5-11.5
Zinc	8.5-10.5	8.5-11.5

[1] Chromium (VI) Solubility from Moore and Ramamoorthy, 1984)

Table 4.4   Comparison of Solubility with pH Range of Highest Metal Removal

The dual-media filter achieved an average overall metal removal in the range of 45-75% depending on the particular metal. It was confirmed that the pH range of highest metal removal also corresponded with the lowest solubility range of that particular metal. Although the average final concentrations were still not below the Criterion Maximum Concentrations for fresh and saltwater, they were still considerably less than the average initial concentrations. However, the concentrations used in this study were based on the

extreme trace metal concentrations that were found in roadway runoff, not the typical or average concentrations. It should also be noted that the loading rate used in this study was higher than what would typically be used. A lower loading rate would result in an increased metal removal. Overall, based on the results obtained in this study, it is concluded that the bed depths used here would better remove trace metals in urban roadway runoff than the BMPs currently in practice.

5   CONCLUSIONS AND RECOMMENDATIONS

Three varying bed depths of a crushed concrete media and a combination of GAC and crushed concrete media were analyzed for their removal capacity of various trace metals in simulated runoff using a bench-scale apparatus. It was concluded that 3 inches of crushed concrete is sufficient to achieve trace metal removal over an extended period of time. Deeper bed depths show no increased benefit of metal percentage removal in the same effluent pH range. However, too shallow a bed depth was found to lead to quicker bed exhaustion and lesser metal removal percentages. Of the six trace metals analyzed, all except chromium achieved significant removal in the crushed concrete columns.

In the dual media column, it was found that fresh GAC does initially cause removal of many of the metals of interest. However, this does not occur for a long period of time and would not occur at all if the GAC was washed prior to filtration. Additionally, the GAC showed an adsorption affinity towards chromium, which was not significantly removed by the individual crushed concrete columns. Therefore, the combination of GAC and crushed concrete is a viable option for the removal of trace metals in urban roadway runoff.

Further research should be done on controlled concrete mixtures of known composition and age to determine their acid neutralization capacities over long periods of time. Additionally, the recovery aspects of crushed concrete should be analyzed in more detail. It would be interesting to see if a relationship exists between recovery of the acid neutralization capacities of the crushed concrete media with the amount of rest time between storm events.

The micro column study should be continued on the dual media to analyze organic removal by the filter. In addition, research should be done on various types of GAC and at various bed depths to optimize removal of contaminants in urban roadway runoff. Finally, a pilot study should be implemented in an urbanized setting to investigate the filter's contaminant removal capacities of actual runoff.

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Phytoremediation of Aged Aromatic Contaminants in Soil Using White Lupin

Basic Information

Title:	Phytoremediation of Aged Aromatic Contaminants in Soil Using White Lupin
Project Number:	2001RI2101B
Start Date:	3/1/2001
End Date:	2/28/2002
Funding Source:	104B
Congressional District:	RI 2
Research Category:	Engineering
Focus Category:	Treatment, Water Quality, Toxic Substances
Descriptors:	Brownfields, Biodegradation, Phytoremediation, Aromatic Contaminants, Chelation
Principal Investigators:	Jose A. Amador, Josef Gorres

Publication

Background

Soils contaminated with petroleum hydrocarbons, chlorinated solvents, and their by-products pose a risk to water quality in the Northeastern U.S. Bioremediation of soils contaminated with these chemicals is often hampered by "aging" of contaminants, a process by which contaminants are sequestered into the nanopore structure of soil, rendering these compounds inaccessible to microorganisms that may degrade them (Alexander, 1999). We conducted a study to evaluate the potential for white lupin (*Lupinus albus*) to improve efficacy of bioremediation of "aged" organic contaminants in soil. Citrate is exuded in large quantities by the roots of white lupin (Gardner et al., 1983; Dinkelaker et al., 1989), and the chelation of iron in iron oxides in soil by citrate may modify the nanopore structure of soil (Gorres et al, 2000) sufficiently to release "aged" contaminants.

Experimental

Soil from the B horizon of a Bridgehampton silt loam was placed in 1-gallon pots. Naphthalene was added to all treatments at an initial concentration 100 μg per kg soil. Treatments were as follows:

I.   Contaminant aged 0 weeks – Planted
II.   Contaminant aged 0 weeks – Not planted
III. Contaminant aged 4 weeks – Planted
IV.   Contaminant aged 4 weeks – Not planted
V.   Contaminant aged 10 weeks – Planted
VI.   Contaminant aged 10 weeks – Not planted

All treatments were incubated under greenhouse conditions. Four replicates of each treatment were used. Planting occurred after the aging period for a particular treatment was completed. After planting the plants were allowed to grow for 8 weeks under P-limiting conditions, at which point the soil was sampled, the naphthalene extracted from soil using methanol/acetonitrile, concentrated on a solid-phase cartridge, and the concentrated extract analyzed by HPLC with UV detection.

Results

The highest mean concentrations of naphthalene were observed after aging for 0 weeks (101 µg/kg), followed by 4 weeks (53 µg/kg) and 10 weeks (12 µg/kg) (Table 1).

Table 1. Effects of white lupin (*Lupinus albus*) on the concentration of naphthalene in soil as a function of aging time. Values shown are means (n=4).

Aging time (weeks)	Naphthalene concentration (µg/kg soil) in:	
	Unplanted	Planted
0	99.3	102.8
4	56.7	50.1
10	14.5	9.5

There appeared to be lower concentrations of naphthalene in planted mesocosms aged for 4 and 10 weeks. However, statistical analyses using a paired *t*-test indicated that there were no statistically significant differences (*P<0.05*) in soil naphthalene concentration between planted and unplanted treatments regardless of time of aging.

Discussion

The disappearance of naphthalene from mesocoms was likely due to a combination of biodegradation and volatilization, which proceeded at a rate that was similar regardless of planting. The absence of an effect of white lupin on naphthalene disappearance from ''aged' contaminated soil may be a matter of timing. Contaminant aging for longer periods of time (e.g. many months to years) – as frequently happens in actual contaminated sites (e.g. Alexander, 1999) – may result in a larger fraction of the contaminant being sequestered in nanopores. This would make it easier to detect effects of lupin root exudates. In addition, effects may be more apparent if plants are grown in contaminated soil for a longer period of time. These data are being used to design a second set of experiments that will improve our ability to detect effects of white lupin bioremediation of aged naphthalene in soil.

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Wet Weather Characterization of Selected Rhode Island Baseline Monitoring Stations

Basic Information

Title:	Wet Weather Characterization of Selected Rhode Island Baseline Monitoring Stations
Project Number:	2001RI2761B
Start Date:	3/1/2001
End Date:	5/31/2002
Funding Source:	104B
Congressional District:	RI 2
Research Category:	Not Applicable
Focus Category:	Water Quality, Surface Water, Non Point Pollution
Descriptors:	baseline monitoring,Water quality
Principal Investigators:	Oran J Viator, Raymond M Wright

Publication

Since 1991, the Civil and Environmental Engineering Department (CVE) has conducted research for the Rhode Island Department of Environmental Management (RI DEM) by establishing a Baseline Monitoring Program for the rivers of Rhode Island. The purpose of the program was to establish a long term, water quality database, under dry weather, or steady state conditions.

This study was the first wet weather study attempted on any Baseline Monitoring Station. The station selected for the study was the Beaver River site, BL06. This site was chosen because it had a U.S.G.S. gaging station, was near the University of Rhode Island where the water quality analysis was conducted, and was an average representation of the watersheds of the baseline stations.

The weather during spring through fall of 2002 was very dry, and the majority of the storm events during that period failed to meet the wet weather criteria set for the study. On September 26-27, 2002 a storm event was captured for this study. Although the duration and rainfall intensity of the event was not optimal, the unpredictability of the weather patterns over the previous several months was a major factor in the decision to sample this storm.

The sampling runs started at 1600 on September 26 and the last sample was taken at 1600 on September 27. Sample intervals were 4-6 hours depending on the rainfall intensity, with a total of six sampling runs completed. Twenty-one water quality constituents were evaluated for the study resulting in 126 analyses run for the wet weather event.

A significant difference between this wet weather event and the dry weather monitoring that occurred previously was the increased fecal coliform counts. The rest of the data is consistent with the average dry weather between 1996 and 2002.

The small differences between dry and wet weather can also be explained by the low intensity and amount of rainfall. The intensity was very light (0.05 inches/ hr or less) and the total was 0.65 inches over a 24 hour sampling interval.

The results do indicate that there may be some FC contamination associated with wet weather events, as indicated by the large increase in FC concentration. The low ammonia

numbers indicate that the source of the FC is not close to the baseline station. All other parameters didn't show an appreciable change during the storm.

A representative sample of the data is shown in Table 1 Conventional Pollutant Concentrations and in Table 2 Biological and Other Dissolved Contaminants.

Table 1 Conventional Pollutant Concentrations

Time	Temp	Conductivity	D.O.	pH	Turbidity	Cl	TSS	VSS
(hour)	(°C)	(mmo/cm)	(mg/L)		(NTU)	(mg/L)	(mg/L)	(mg/L)
1730	16.0	100	8.70	6.38	2.95	15.0	1.92	1.80
2330	15.2	79	8.75	5.80	1.85	10.8	0.98	0.86
0600	15.0	79	8.40	6.09	2.55	10.4	1.48	1.44
0945	15.0	80	8.35	6.22	1.75	10.2	1.58	1.42
1215	15.5	80	8.40	6.22	2.45	9.6	1.64	1.32
1600	16.0	79	8.40	6.25	1.85	10.1	1.56	1.40

Table 2 Biological and Other Dissolved Contaminats

FC	BOD_5	$NH_3 - N$	$NO_3 - N$	$PO_4 - P$	TP	Na	Hardness	Diss Cu	Diss Pb	Diss Cd	Diss Fe
CFU/100ml	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
150	0.43	0.071	0.42	0.013	0.069	7.19	10.13	1.10	0.95	0.15	194
930	0.48	0.048	0.63	0.007	0.065	7.31	9.76	0.70	0.90	0.17	352
1,700	0.52	0.064	0.81	0.005	0.042	8.48	9.56	0.35	0.40	0.05	397
1,400	0.57	0.040	0.57	0.004	0.014	7.59	9.87	0.70	0.95	0.03	266
1,300	0.45	0.046	0.65	0.004	0.010	6.15	11.16	0.60	0.75	0.01	334
1,800	0.35	0.059	0.93	0.004	0.006	6.41	10.25	0.65	0.60	0.15	732

Information Transfer Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	7	0	0	0	7
Masters	3	0	0	0	3
Ph.D.	2	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	11	0	0	0	11

Notable Awards and Achievements

Publications from Prior Projects