

**ESC DOCUMENT REVISION RECORD**

**Document Number/Title:**

*Initial Field Deployment Results of Green PCB Removal from Sediment Systems (GPRSS)".*

Revision	Date	Office of Primary Responsibility	Description of Change	Affected Page
Basic	4/15/14	Chemical and Biological Sciences	Initial Issue	All

**Verify this is the current version before use.**

## Final Report: TO 165

The goal of this task order was to complete optimization and development of the Green PCB Remediation from Sediment Systems (GPRSSs) technology, culminating in the production of functioning demonstration test units which would be deployed at a suitable demonstration location. This location would be selected in conjunction with Toxicological & Ecological Associates who have entered into a SAA with NASA to partner with and further develop this technology. The GPRSSs technology was initially developed under ESC Task Order 83 with the purpose of providing a green remediation technology capable of *in-situ* removal and remediation of polychlorinated biphenyls (PCBs) from contaminated sediments. The core concept of the technology, a polymeric blanket capable of absorbing PCBs when in contact with contaminated sediments was then transitioned to Task Order 165 where the primary objective was to fully design and optimize a functioning test unit capable of testing the theoretical and laboratory-scale concepts in a real-world situation. Results from both task orders are included in this report for completeness, although Task Order 165 focused on the blanket design and the small-scale field demonstration in which is currently still ongoing in Altavista, VA.

Initial work on this project had focused on determining the most effective sorbent material to use for the removal of PCBs from contaminated sediments.

Initial tests involved studying the capability of a variety of polymeric materials to remove PCBs from aqueous solution. Some of the polymers that were tested included fluorinated ethylene propylene (FEP), polyethylene (PE), polypropylene (PE), nylon, polystyrene, polytetrafluoroethylene (PTFE), and polyvinylchloride (PVC). The vial studies showed that while all of these materials seemed to absorb some amount of PCBs from aqueous solution, clearly some were capable of higher levels of removal. These initial tests indicated that FEP removed the highest percentage of contaminants from solution. The data from this study is given in Table 1.

**Table 1: FEP removal of PCBs in Water**

% Removal from Water Continuum			
	2 weeks	3 weeks	6 weeks
FEP1	54%	60%	27%*Outlier
FEP2	66%	50%	73%

Sphere of influence studies were completed on pipette bulbs in order to help determine final spacing of spikes on demonstration units. Based upon initial materials testing (done by actual insertion of 3-D printed models being inserted into the river), the demonstrations units were going to have a spike-to-spike spacing of 2". In order to determine how far the effective reach of the individual spikes would be in a sediment environment, a study was performed where EtOH-filled pipette bulbs were placed into contaminated sediments (60 mg/kg soil 1254, sediment was dried and sieved prior to spiking) for a period of 3 weeks. After three weeks had passed, the sediment was removed and tested at varying distances from the pipette bulb to determine how much PCBs were remaining. This study was run in triplicate, and 3 different distances were chosen for analysis from each sample. The data is shown in the figures/tables below.

A set of vial studies was conducted to study the effect that surface contact between various to

**Table 2: Polymer strips in sediment system either stationary or moved bimonthly**

	Stationary		Mobile			
	1 month	2 month	1 month	2 month	1 month	2 month
	3.2%	3.3%	3.2%	3.3%	3.2%	3.3%
ECTFE	6.2%	10.7%	6.2%	10.7%	6.2%	10.7%
ESD100	1.7%	3.6%	1.7%	3.6%	1.7%	3.6%
FEP	4.0%	5.0%	4.0%	5.0%	4.0%	5.0%
Nylon 11	3.5%	3.9%	3.5%	3.9%	3.5%	3.9%
PA66	*	10.9%	*	10.9%	*	10.9%
PE	2.0%	3.5%	2.0%	3.5%	2.0%	3.5%
PFA	3.1%	4.5%	3.1%	4.5%	3.1%	4.5%
PVDF	4.4%	6.1%	4.4%	6.1%	4.4%	6.1%
TPX	2.7%	3.7%	2.7%	3.7%	2.7%	3.7%
PTFE	7.9%	4.4%	7.9%	4.4%	7.9%	4.4%

\* samples were lost during the extraction process

evaluate the effectiveness of a wide range of polymeric materials for the removal of polymers and contaminated sediments had on the absorption rate of the PCBs, as well as PCBs in a sediment system. A parallel set of experiments were conducted, one in which a control set of polymer strips were kept stationary and a second experiment in which a mobile set of the polymers were moved every month (for a 3-month period) Multiple polymers were tested, including ECTFE, ESD-100, FEP, Nylon 11, PA-66, PE, PFA, PVDF, TPX, PTFE, and PVC. The resulting concentrations found in the each of the polymer strips are shown below in Table 2. Results from this study are reported in % removal of PCBs as compared to the original amount spiked into the sediment vials (for this study, a total of 200 µg persample). As can be

seen from the data above, all of the polymers tested in this study showed some degree of affinity for the PCBs in the sediments, which is in agreement with the data originally acquired from the studies performed in both aqueous systems and contaminated sediments. However, while some polymers appeared to perform better than others (most notably PE and ESD-100), there does not appear to be a significant difference between the various polymers tested. This data supports two conclusions. First, the chemical identity of the polymer material is less important than the surface area in contact with the sediments as no significant statistical difference between the mobile and stationary polymer studies was noted. The second conclusion is that increased surface area alone may not be sufficient to obtain the removal efficiencies necessary to produce a successful remediation technology. Based on the previously obtained results, it becomes apparent that the PCB removal may require an additional driving force, something to impart a motivating factor to help the contaminants leave the surface of the sediments and to cross into the polymeric lattice.

The data obtained from previous studies indicates that while PCBs are absorbed by a variety of polymers, little variability between the various types of polymeric materials tested was noted. A sediment study in which an ethanol interior was included within the polymer was initiated in hopes of introducing a concentration gradient (similar to what was used in Emulsified Zero-Valent Iron, or EZVI) to increase the transport of the PCBs through the polymeric material. The ethanol interior would have a greater affinity for PCBs than the aqueous exterior, allowing for transport from the membrane itself into the ethanol solvent. Additionally, it was thought that the ethanol itself may help to open the lattice

structure of the polymeric materials, allowing for increased transport of contaminants to the interior. This data strongly supports the theory that the use of an ethanol interior enhances the transport of PCBs from the contaminated sediments into the polymer interior. Table 3 shows the distribution of PCBs within the polymer and the ethanol interior, clearly indicating the complete traverse path of the contaminant from the sediments to the solvent interior. Within a single month, quadruplicate test vials indicate that approximately 50% (sediment originally spiked with 200 µg of Arochlor 1254) of the PCBs can be removed from the sediments using stationary, ethanol-interior polyethylene tubes. This data strongly supports the theory that the use of an ethanol interior enhances the transport of PCBs from the contaminated sediments into the polymer interior.

**Table 3: PCB Distribution within the Polymer Lattice within the EtOH interior**

<b>% of PCBs removed by Ethanol-filled Polyethylene (1 month Study)</b>			
	<b>Interior</b>	<b>Within Polymer</b>	<b>Total</b>
Pipet 1	35.4	14.0	49.3
Pipet 2	31.7	11.0	42.7
Pipet 3	35.9	12.0	48.0
Pipet 4	41.9	17.6	59.6

A more complete sediment study of new obtained polymers was initiated to determine the different absorption capabilities of materials such as norprene, acetonitrile butadiene styrene, nitrile, viton, gum rubber (isoprene) and butyl rubber. The sediment study was setup similar to previous

**Table 4. Additional PCB Polymer Compatibility Tests – No EtOH Interiors**

Sample ID	% PCB Removal		
	3 Weeks	7 Weeks	17 Weeks
Black Norprene Tubing	5.73%	7.96%	10.63%
White Norprene Tubing	2.15%	4.54%	4.60%
Latex Glove	0.93%	3.14%	4.14%
Thick Nitrile Glove	0.95%	0.31%	1.59%
Abrasion Resistant Gum Rubber (5/8")	1.03%	3.43%	1.86%
Natural Gum Foam	3.04%	14.17%	20.26%
Abrasion Resistant Gum Rubber (1/16")	3.02%	5.42%	8.27%
Weather Resistant Butyl Rubber	3.44%	7.14%	18.46%
Weather Resistant Butyl Rubber	3.85%	9.02%	9.87%
Viton Mat	4.22%	7.30%	6.03%
Black Viton Tubing	1.89%	0.94%	2.76%
White Viton Tubing	0.99%	0.63%	0.91%
Butyl Rubber (glove)	3.99%	3.48%	4.10%
ABS	2.95%	4.71%	3.89%

studies of this type, although vials were spiked with a total of 600 µg of Arochlor 1254. For polymers received as tubing, 1 cm length pieces were used for each sample. For samples received as a film/roll, pieces 1 cm<sup>2</sup> in area were used. Duplicate samples were pulled for analysis after 3, 7, and 17 weeks. Samples were extracted as in the last study, where the polymer itself was extracted and analyzed. The extract was then analyzed using GC-ECD (with standards run to confirm concentrations). The concentration within each extract was then back-calculated to a total mass of Arochlor 1254 removed by each polymer (for comparison purposed to the original spike concentration of 600 µg). This data is shown in the in Table 4 and is given in % removal. The best

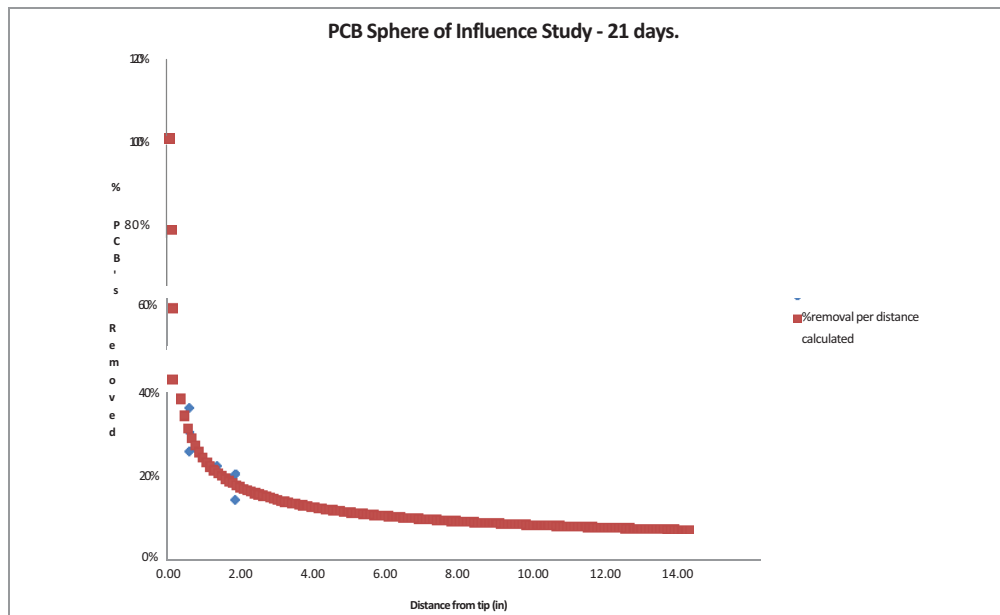
performing polymers (after 17 weeks) were the natural gum foam rubber, the black norprene tubing, the abrasion resistant gum rubber (1/16"), and the weather resistant butyl rubber (highlighted in yellow within the data table). These samples showed the highest removal capabilities as well as the highest increases (between sampling periods) during the study. A second companion study was run concurrently with this one to measure the affect a protonated solvent (ethanol) would have on the

removal capability of the polymers. Previous studies have shown this to have a capability of increasing the removal capabilities of the polymeric material, most likely due to a concentration gradient effect created by having an ethanol interior and the possible opening of the polymeric lattice to allow greater transport. For this study, the Thick Nitrile gloves were chosen due to convenience factors. It was relatively simple to use the finger tips of the glove as a natural reservoir for the ethanol (it was more difficult to achieve this with film/tubing). A 3.8 cm section of the fingertip was used for each sample, and 5 mL of ethanol was added. The glove tip was then sealed (using zip-ties) and submerged within dried, spiked sediment (prepared the same as the previous study), and the sediments were brought to incipient wetness. Duplicate samples were pulled and analyzed at the 3 week and 7 week marks. The ethanol interior was removed from the nitrile glove material; the nitrile polymer and the ethanol interior were analyzed separately (hexane was used as the solvent). Data from this study is given in Table 5. Again, the data is presented as % removal of PCBs as compared to the original 600 µg of Arochlor 1254 that was used to spike each sample vial. The data shows that PCBs are transporting across the polymer to the interior, although the concentration found within the ethanol interior is not extremely high, nor does it vary much in absolute PCB removal between the 3 and 7 week period. However, the nitrile polymer itself shows a higher removal rate (compared to nitrile without an ethanol interior as seen in Table 3) which indicates that the interior is increasing the removal rate/capacity. At the 3 week mark, ~20% of all PCBs were found within the nitrile glove tip (~120 µg Arochlor 1254) and at the 7 week mark the removal has increased to ~68% (~410 µg Arochlor 1254). The duplicates were in good agreement with one another. It is possible that ethanol was leaching through the nitrile glove material and into the sediment, which may have falsely inflated the PCB removal numbers (by helping remove the PCBs from the sediments). It appeared that both samples were intact, and that most (if not all) of the ethanol was still within the glove material (an exact volume was not determined). Further studies will have to be performed to investigate this possibility; previous studies have shown that ethanol interiors can provide a marked increase in removal capacity. This would argue for the fact that at least some of the increased removal is due to ethanol interior. Perhaps the most salient point to note from the data presented in the last two studies is that the total percentage of PCB removed was greatly increased through the use of an ethanol interior, although the nitrile glove material is not as efficient at PCB absorption as some of the other polymers that were tested (such as the natural gum foam and weather resistant butyl rubber). If these other polymers can be combined with an ethanol interior, it is hoped that the same sort of increase will occur in the PCB removal capacity of the materials.

**Table 5: PCB Distribution within Nitrile Gloves with EtOH Interiors**

Sample ID	% PCB Removal	
	3 Weeks	7 Weeks
Nitrile Glove A	19.19%	66.13%
Ethanol Interior A	4.99%	2.47%
EtOH Interior + Glove A	24.18%	68.61%
Nitrile Glove B	19.42%	70.13%
Ethanol Interior B	4.34%	2.49%
EtOH Interior + Glove B	23.76%	72.62%

Sphere of influence studies were completed on pipette bulbs in order to help determine final spacing of spikes on demonstration units. Based upon initial materials testing (done by actual insertion of 3-D printed models being inserted into the river), the demonstration units were going to have a spike-to-spike spacing of 2". In order to determine how far the effective reach of the individual spikes would be in a sediment environment, a study was performed where EtOH-filled pipette bulbs were placed into contaminated sediments (60 mg/kg soil 1254, sediment was dried and sieved prior to spiking) for a period of 3 weeks. After three weeks had passed, the sediment was removed and tested at varying distances from the pipette bulb to determine how much PCBs were remaining. This study was run in triplicate, and 3 different distances were chosen for analysis from each sample. The data is shown in the Figure 1 and Table 6 below.



**Figure 1: Sphere of Influence Study using Polyethylene bulbs**

**Table 6: Sphere of Influence Study Results**

Distance (in.)	% Removal
0.63	30%
1.38	21%
1.88	16%

Based upon this data, it was decided to modify the design to a spike-to-spike distance of 3", which would allow for easier insertion of the PCB "blanket" into the sediment, and still give ~20% removal at the 21 day mark. Comparable studies will be completed with mass-produced spikes (currently underway).

A commercial vendor was chosen (after a bidding process was completed) to provide a spike mold which is being used to mass produce spikes from several different materials including high-density polyethylene (HDPE), low-density polyethylene (LDPE), and polypropylene (PP). There were initial problems with the manufacturing process which needed to be worked out; initial samples were “short-shots” as can be seen in the image below (Figure 2):



**Figure 2. Initial spike samples with “short-shot” problems from Quick Parts**

After several discussions with the vendor, the designs of the mold were modified to correct for this and a new set of samples were produced which have been received and are currently undergoing testing for PCB removal capability. Three sets of 25 spikes of each of three polymer materials have been received for sample testing purposes, final changes are being incorporated into the mold for the initial production run of 500 spikes of each polymer type (we have the ability to make more in the future). The mold design and an image of the HDPE sample spike are shown below.



**Figure 3. Design schematics for production mold of spikes and sample of HDPE spike**



The sample spikes are currently being tested for removal capability and sphere of influence (similar to how the pipette bulbs were tested) in contaminated sediments. All three polymeric materials are being tested in triplicate. 500g of dried and sieved sediments were spiked to a concentration of 60ppm with Arochlor 1254 for extraction studies with the injection molded polymer spikes. Figure 4 shows an example of the polymeric spike study which were conducted.

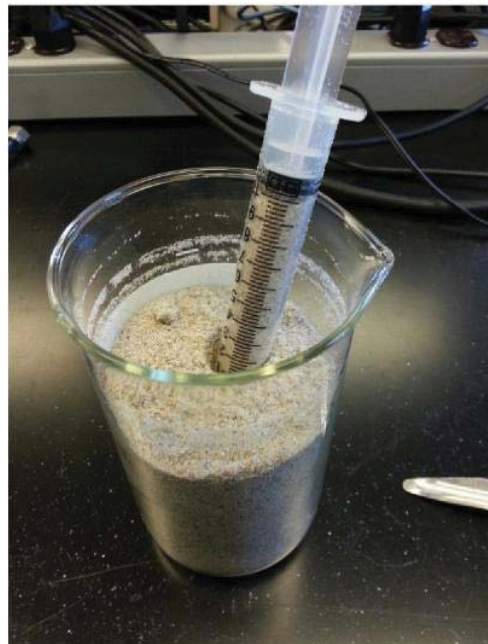


**Figure 4 HDPE spike in PCB contaminated sediments**

The spikes were left in the sediments for 5 weeks before being removed and analyzed. Initially, the interior ethanol as well as the spike itself was analyzed to determine the total amount of PCBs which were absorbed during the course of the study. The data for this study has been normalized to show the relative diffusion of PCBs through the surface of the polymeric materials per unit time, to allow for an easier comparison of the different materials ability to absorb the contaminants in sediments. The data is given in Table 7. The samples showed that LDPE removed slightly more PCBs than the HDPE with both outperforming PP. Also, the HDPE kept more of the removed PCBs inside the polymer, whereas the LDPE allowed the movement of more PCBs into the internal ethanol. Additional analysis was performed on the sediment from each of the samples. For this analysis, small sediment cores were taken from each of the sample using a disposable 10mL plastic syringe. The tip of the syringe is cut off, and the remaining body of the syringe is plunged into the sediment (with the plunger still attached). Once at the appropriate depth, the plunger is withdrawn, which also pulls up a 10mL sediment core, as shown in Figure 5.

**Table 7: Results of Sediment Study using HDPE, LDPE, and PP Manufactured Spikes**

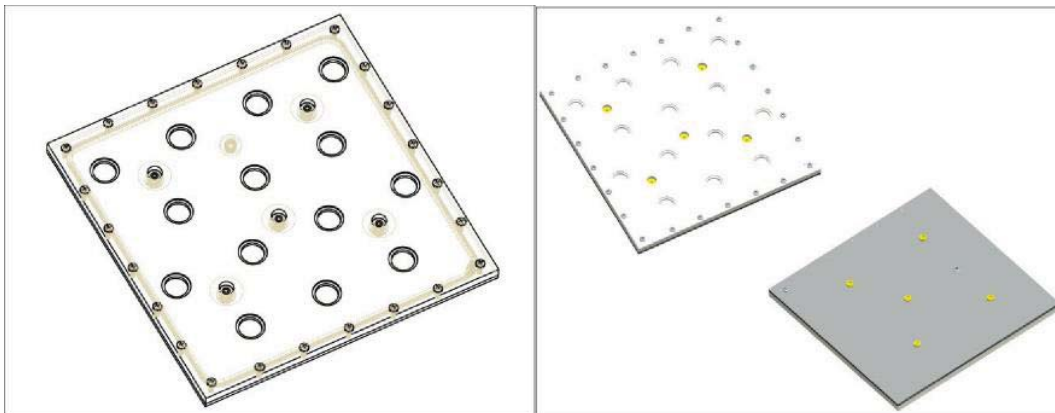
Sample ID	Diffusion Rate (ug/in <sup>2</sup> /week)
HDPE	12.48
LDPE	13.42
PP	8.20



**Figure 5 Sediment coring of contaminated PCB samples**

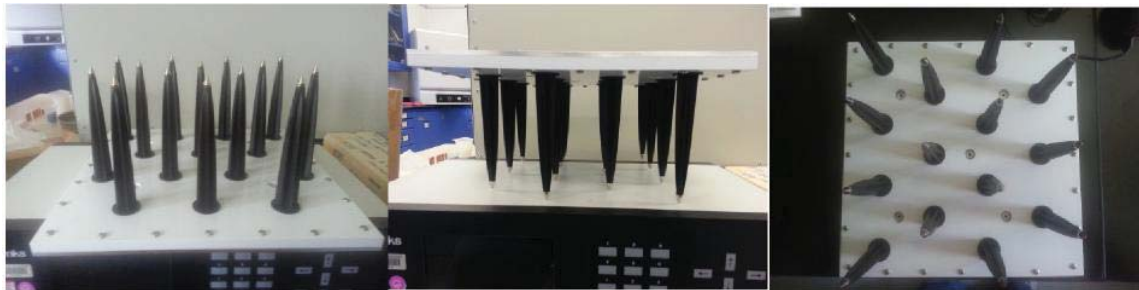
Each vial had four different core samples analyzed to attempt to profile PCB removal. The data consistently showed removal of PCBs at a higher rate directly adjacent to the spikes than against the walls of the container, which is to be expected. An unexpected piece of data, however, was that PCB concentrations were much higher in the shallow core samples (upper half of the container) than the deeper core samples (lower half of the container). Some control samples were run and confirmed this to be an artifact of the spiking method combined with poor mixing. The upper layers of sediment act as a filter, binding excess PCBs as the solvent penetrates deep into the container. The shape of the container did not allow for good mixing, leaving poor homogeneity. This will be corrected in future experiments by spiking a single large batch of soil and performing manual mixing/agitation to ensure adequate homogeneity. From the results of the previous polymer spike study, it was decided to go with HDPE spike for the first deployment test. Although LDPE had a slightly higher PCB absorption rate, HDPE had better mechanical properties which were considered vital for the insertion of the "blankets" into the contaminated sediments.

Manufacturing of the prototype units was completed in-house, during which several issues with the initial design of the prototype "blanket" units were discovered. These first units had leak points at the corners, which was due to the fact that there were too few bolt holes (3 per side, none in the corners) in the initial design, which has since been corrected. Additionally, the underside of the "blanket" was thickened by 0.100", to add additional strength to the design and less material was removed from the sides to accommodate the additional bolts that were added. Design drawings of the front and back of the demonstration unit are shown in Figure 6. The pop-rivets can be seen in the design, which provide vacuum relief when the system is inserted into a sediment system. In addition, the top-view shows the addition of a venting port in one corner, which will allow for easier filling of the system with ethanol.



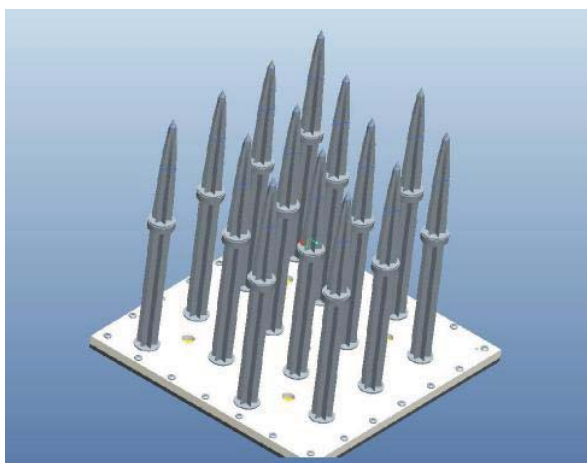
**Figure 6. Current baseplate/top-plate design drawing of PCB "blanket"**

This unit was leak tested using the HDPE manufactured spikes and appeared to be leak-proof after a period of several days, indicating the current design changes have solved the initial problems. The current volume is 500mL per "blanket" segment. Figure 7 shows several views of a fully-assembled demonstration unit.



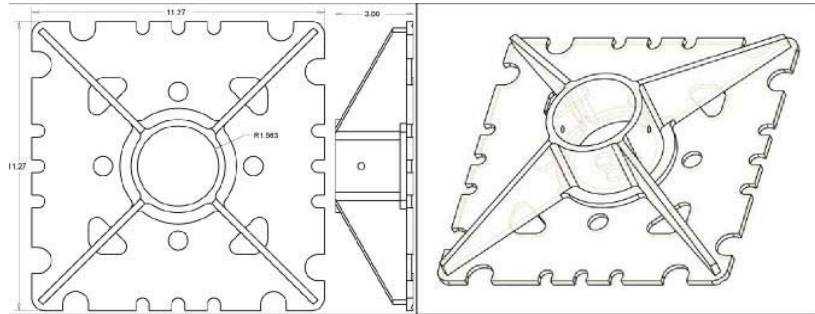
**Figure 7. Initial demonstration unit (fully assembled)**

Twenty production units (based upon this design) were prepared for use for in the field demonstration that is planned for September 2013 at Altavista, VA at a sump pond which has been contaminated with PCBs (consistent with Arochlor 1248) at a depth of up to 18 inches. The original field demonstration site was going to be in Louisiana with contamination only in the top 6" of the sediments; however the Altavista site had contamination at deeper depths. Because of this, a polymeric adapter was designed that could be attached to the existing manufactured spikes and blanket to extend the reach of the GPRSS technology. These extenders are manufactured out of HDPE and are of the same geometry as the currently used spikes, as can be seen in Figure 8. 500 of the HDPE extenders have been ordered from the vendor, and the samples have just arrived for initial evaluation. These extenders will allow for flexibility in the deployment of the blankets, allowing for testing at various depths in the sediments. The extenders were not necessary for the Altavista field demonstration, due to the flocculent nature of the sediment found at the site. Additionally, some structural issues were discovered that proved it was easy for the adapters to be broken, or “sheared”, if force perpendicular to the spikes were applied during the insertion process complicating their use during the initial field test of the GPRSS technology.



**Figure 8: Design of PCB "blanket" with extenders for deeper contaminated sediments**

The next step was to test the ability to insert this demonstration unit into an actual sediment system. To facilitate insertion of the PCB “blanket” system into sediment as rapidly and easily as possible, a post-hole driver has been ordered which will be used to “tap” each segment of the “blanket” into the sediment. An adapter has been designed which will be fitted to the post hole driver and fit over the “blanket, allowing for equal force to be placed on all areas of the aluminum top-plate as the “blanket” is driven into the sediment. The initial concept for the adapter plate is shown in the following figure:



**Figure 9. Design of adapter for PCB “blanket” system**

The adapter plate was produced from billet aluminum, and an extension rod was fitted to it to allow for it to insert the PCB “blankets” into contaminated sediments under several feet of water. The individual Skidril post-hole driver and driver-adapter are shown below, as well as the assembled system (Figure 10).



**Figure 10: 4-stroke post-hole driver, driver-adapter, and assembled insertion system**

The assembled insertion system was tested on one of the prototype PCB “blankets” at a local river to simulate field sediment conditions.



**Figure 11. Post-hole driver inserting blanket and blanket in various stages of insertion**

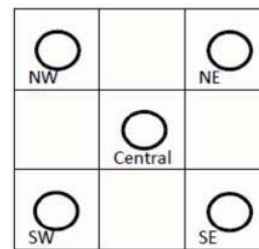
The insertion system performed as expected, and offered a good deal of control during the insertion process. The insertion system itself is fairly heavy, and the weight of it alone allowed for a good portion of the "blanket" to be driven into the sediments (so manual operation of the adapter may be an option in the field), although the post-hole driver may become necessary when using the extenders. Again, due to the flocculent nature of the contaminated sediments found at the Altavista field site, the automated insertion system was not required during the field demonstration.

The location used for the demonstration of the GPRSS technology was the secondary site choice, as the original site was unavailable at the time of deployment. Arrangements to perform the deployment (permitting, logistics, etc...) were handled by TEA, as was the actual deployment of the GPRSS technology itself. NASA/ESC sent a representative as a technical consultant for the deployment process whose responsibilities included addressing any specific issues which arose with the technology during the demonstration. An initial assessment had previously been performed on the site, which was a sump pond at a wastewater treatment facility in Altavista, VA (shown in Figure 12) in 2003 which showed PCB concentrations from below 100ppm to ~17,000ppm. Several different possible treatment options were presented at the time including capping, removal and treatment, removal and containment, in-place treatment, and to take no further action. As the initial evaluation was voluntary at the time, it appears that the site owners chose to take no action at that time.



**Figure 12. Altavista Field Demonstration Site**

In September 2013 a small-scale deployment of the GPRSSs technology was undertaken at the Altavista contamination site. For this study, two separate 9ft<sup>2</sup> plots were chosen to be tested. Each plot was treated with 9 individual polymer “blankets” in a 3x3 grid. Pre-treatment samples were taken from the center and the northeast, northwest, southeast, and southwest corners of the box as shown in the figure below. An overlying water sample was also taken for analysis. All samples were split and sent to both KSC and a 3<sup>rd</sup> party laboratory for independent analysis. The sediment at this site was found to be extremely flocculent, which made the use of the automated insertion device unnecessary. Metal boxes were constructed on-site to mark the test areas and contain the “blankets” during the demonstration. The “blankets” were weighted and attached to fishing bobbers so that they could be deployed/removed and located easily during the testing process. Figure 14 shows Greg Booth from TEA preparing to deploy the “blankets” at the site.



**Figure 13. Polymer Blanket Deployment Layout**



**Figure 14. Preparation for “blanket” Deployment**

The “blankets” were pre-assembled and shipped to the site early. A peristaltic pump was used to fill each segment with ethanol the morning of the deployment. The initial deployment was made on 9/24/13, and was originally scheduled to end in December (~3 months). However, due to unexpected weather conditions in the area, the first sample retrieval was delayed until early February (2/4/14). At this time the “blankets” were removed and emptied of ethanol, and post-treatment sediment samples were taken for analysis. All samples were split and sent for analysis (as before) to both KSC and a 3<sup>rd</sup> party laboratory for independent testing, including an overlying water sample. The “blankets” were then refilled with fresh ethanol and re-inserted in their previous positions for a second application.

Third-party analysis of the 1<sup>st</sup> set of samples taken from the field site showed that nearly 80% of the sediment samples tested had been remediated to below the EPA mandated action limit of 50mg/kg, which corresponds to the analysis performed in parallel of the sample splits at KSC. The data for both the pre- and post-treatment (19 week exposure) analysis of the sediment samples by the third party lab is shown below in Table 8 and Table 9.

**Table 8. Pre/Post Conc. for Box 1 (3<sup>rd</sup> Party)**

Sample ID	Conc. (ppm)	
	9/24/2013	2/4/2014
NW	74.2	26.8
NE	92.1	26.2
C	85.1	66.9
SW	151	28.3
SE	144	21.4
Overlying water	N/A	2.4

**Table 9. Pre/Post Conc. for Box 2 (3<sup>rd</sup> Party)**

Sample ID	Conc. (ppm)	
	9/24/2013	2/4/2013
NW	226	145
NE	84.3	28.1
C	120	40.3
SW	83.7	72.1
SE	106	18.6
Overlying water	2.7	6

The 3<sup>rd</sup> party data shows that 7 of the 10 data points were brought below 50mg/kg during the initial exposure to the GPRSS technology, with an approximate removal of 60% of the PCBs (according to the pre-treatment concentrations). The corresponding analysis at KSC was in agreement with the 3<sup>rd</sup> party analysis, showing a large amount of removal from the sediments during the application of the GPRSSs technology. Pre- and post-concentrations for Box 1 and Box 2 are shown in Tables 10 and 11.

Table 10. Pre/Post	Conc. for Box 1 (KSC)		Table 11. Pre/Post	Conc. for Box 2 (KSC)	
	Conc (ppm)			Conc (ppm)	
Sample ID	9/24/2013	2/4/2014	Sample ID	9/24/2013	2/4/2014
NW	303.1	13.9	NW	377.9	29.6
NE	381.2	26.6	NE	291.9	31.3
C	247.6	18.3	C	273	12.6
SW	349.2	49.6	SW	214.8	51.4
SE	301.1	23.8	SE	245.9	89.5

The analysis at KSC showed greater removal from the sediments, however the extraction efficiency was not known for this sediment so the actual removal is less than what is shown (in line with what was seen by the 3<sup>rd</sup> party laboratory). Another factor which may account for the difference seen in the concentrations is that KSC uses a modified version of EPA Method 8082A for the analysis of PCBs as compared to the 3<sup>rd</sup> party laboratory. However, both laboratories do concur that the majority of post-treatment sediment samples were brought below the EPA action limit of 50mg/kg for PCBs. Analysis of

the ethanol interior at KSC verified the presence of PCBs, although the concentration was low, which points to the majority of the contaminants being in the polymer “blankets” themselves. Analysis of the “blankets” will allow for the confirmation of this; however they are currently deployed in a second application at Altavista. Current plans are to analyze additional post-treatment sediments, as well as the blankets and the new ethanol interiors once they are removed in August in an attempt to perform a mass balance. One issue of concern was the increase in the surface water concentrations, which may indicate some mobilization of the contaminants from the sediments due to the GPRSS technology (it must be confirmed if these overlying samples were taken before or after the “blankets” were deployed). This could be possible if the ethanol were leaking, but a volume check after the 1<sup>st</sup> deployment didn’t seem to show any volume loss and a density analysis of the recovered ethanol showed it to be pure (water was not leaching in and displacing the ethanol).

The initial results from the Altavista, VA field deployment are being presented at the upcoming Battelle 9<sup>th</sup> International Conference on Remediation of Chlorinated and Recalcitrant Compounds in Monterey, California held May 19-22, 2014. An updated abstract including the preliminary results from the field deployment has been submitted and accepted, and a proceedings paper will be submitted for publication with the conference proceedings as well. Personnel from the NASA Technology Transfer office will also be hosting a booth at the conference to help promote the GPRSS technology to those attending, with an expected turnout of between 1,500 and 1,700 scientists, regulators, and other environmental professionals from more than two dozen countries.

Additionally, as of this time two New Technology Reports have been submitted and accepted on various aspects of this project (eNRT# 1368464383 and eNRT# 1348866029) as a patent has been filed on the technology (Patent # 13 / 895,717).