POLYCHLORINATED BIPHENYLS IN STORMWATER SEDIMENTS AT BERNALILLO COUNTY, NEW MEXICO

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ABSTRACT

In response to 2009 findings by the NM Environment Department (NMED) that stormwater from urbanized areas in Bernalillo County carries concentrations of polychlorinated biphenyls (PCBs) in excess of water quality criteria for the Rio Grande[1], Bernalillo County worked with the US Geological Survey to conduct a 2010 stormwater sediment screening program to assess historical PCB discharges from four County stormwater systems. The results illustrated that estimated PCB levels in County stormwater are consistent with levels observed by NMED, and indicated that PCB aroclors used for a wide range of application prior to 1950 remain in the County watershed and are transported by stormwater to the Rio Grande. Further sampling at the County Sanchez Farms stormwater facility established that passive sediment removal followed by treatment in a constructed wetlands effectively reduced the concentration of PCBs in stormwater. Using CWA 319(h) grant funds, Bernalillo County has retained a consulting firm to assist with an evaluation of BMPs applicable to its stormwater facilities. The County has also obtained state seed funding to begin installing one or more structural BMPs recommended in the evaluation.

INTRODUCTION

Production of PCBs began in 1929, and was banned in 1979. PCBs comprise 209 possible congeners, based on the number and location of chlorine atoms attached to carbon atoms in two adjoined benzene rings. The toxicity (e.g. skin lesions) and probable carcinogenicity of PCBs has been known since 1937, and was the subject of a Harvard School of Public Health conference that year. PCBs occur in the water environment primarily attached to suspended organic sediments.

Aroclors are brand-name mixtures of PCB congeners produced by Mansanto Corporation between 1930 and 1977. The Aroclor numbering convention (e.g. 1254, 1260) indicates th e number of carbon atoms in the chemical structure (always 12), followed by the percentage of weight attributable to chlorine (e.g. 54%, 60%). Aroclors 1254 & 1260 were used pre-1950 and Aroclor 1242 was used between 1950 and 1971. As illustrated in Table 1, PCB Aroclors were used in a wide variety of applications until they were banned in 1979.

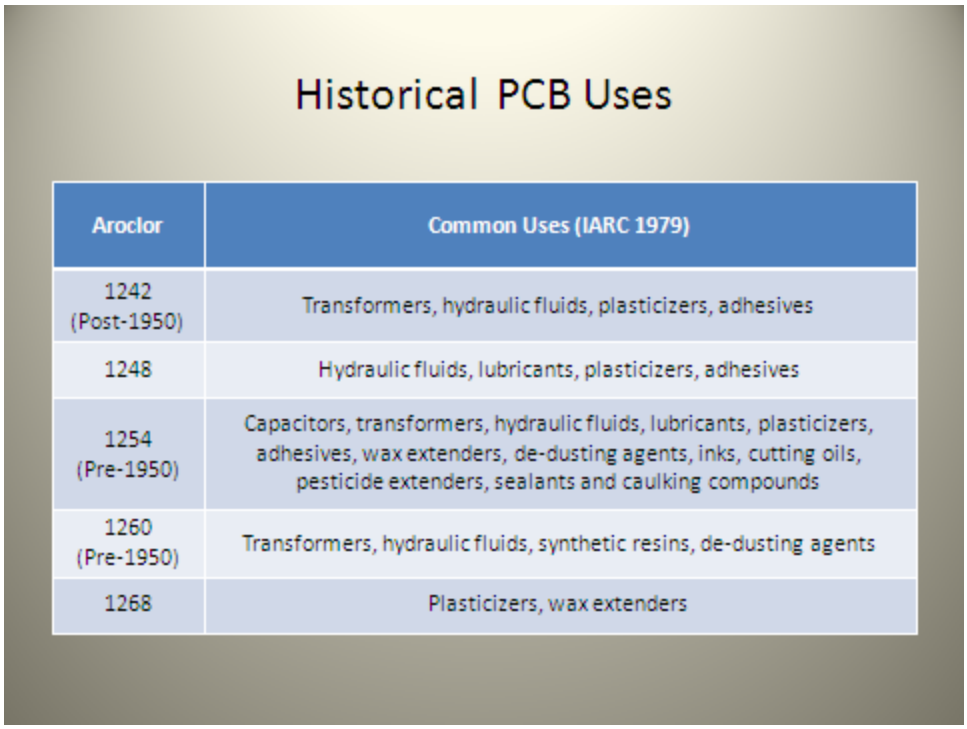


Table 1. Historical Uses of PCB Aroclors

PCBs have recently been detected in the Rio Grande near Albuquerque by the New Mexico Environment Department (NMED)[1]. The NMED results strongly suggest that the PCBs detected in the Rio Grande originated from the Albuquerque area and the urbanized watersheds are now under increased scrutiny. Bernalillo County Public Works Division is taking a proactive approach toward identifying any potential sources of PCBs in County stormwater that discharges to the Rio Grande. Since PCBs strongly adsorb onto organic sediment particles[2], it was determined that bottom sediment at seven County stormwater sites, plus an additional field blank, would be sampled by the US Geological Survey (USGS) to determine if sediment deposited at the outfalls of several watersheds contain PCBs. PCB occurrence correlates well with total organic carbon (TOC) occurrence based upon previous studies[2], so each sample was also analyzed for TOC. Samples were also analyzed for total dry solids content.

METHODOLOGY

The four major storm pump outfalls operated by Bernalillo County and sampled by the USGS in this study were the Alameda Pump Station, the Sanchez Farms Stormwater Facility, the Paseo del Norte Pump Station and the Adobe Acres Pump Station (Figure 1). All samples were collected on June 9, 2010, during a period of little storm runoff. Care was taken to ensure that the sediment sampled was that deposited by previous storm runoff events. One composite sediment sample was taken at the outlet of each of the first three sites. The Adobe Acres Pump Station discharges into a riverside drainage ditch, so a composite sediment sample was taken from sediment accumulations immediately upstream of the pump station sump for that location.

The Sanchez Farms site is characterized by a unique design of multiple inter-connected wetland areas before stormwater reaches the discharge pumps. For this reason, a total of three sediment samples were collected in this watershed. One was collected from within the concrete inflow

filtration/sedimentation structure upstream of any wetlands, a second was taken immediately upstream of the storm pump sump, and a third sample was taken on the Rio Grande floodplain where the pump discharge flows onto the Bosque floor before flowing to the river.

The control site was located in a detention dam structure in the upper reaches of the Embudo Canyon on the east side of Albuquerque. This site is on the west side of the Sandia Mountains and upstream of any urban development, so it should represent the background for PCBs in sediments in this area, unaffected by urban runoff.

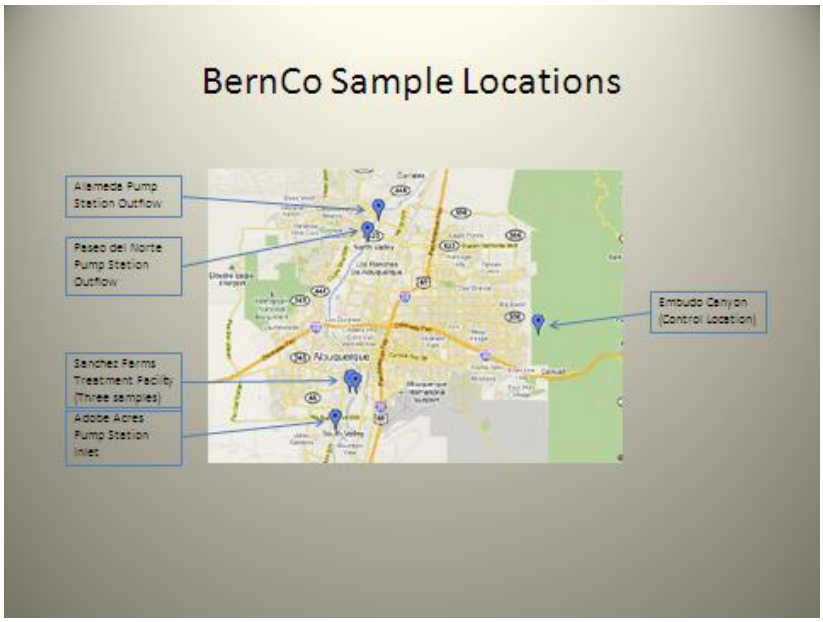


Figure 1. Bernalillo County Sediments Sampling Locations

To establish the validity of sampling techniques employed, a field blank was also produced using PCB-free control soil obtained from the NM Scientific Laboratory Division (NMSLD). It should be noted that no PCBs were detected in the control soil by NMSLD using the Aroclor analytical method. No certification of analyses is available for this material, however, the NMSLD had previously baked and analyzed the soil and found no PCBs over their minimum detection limit of approximately 4.5 parts per billion. The field blank was handled in the field using the same transfer methods used for environmental soil samples.

A shovel was used to lift up a block of undisturbed sediment, representing approximately the upper three inches of soil. Care was taken to not touch the surface of the displaced soil block with the shovel. A clean, stainless steel spatula was used to clear off the top approximately one inch of soil and a small portion of the undisturbed center of the sediment block, approximately the size of a golf ball, was placed in a clean baked glass sampling jar for PCB analysis. A second sample was placed in a separate jar for TOC analysis. The identical procedure was repeated at two more locations within approximately a ten-foot radius at each sampling site. Each of the three subsamples for PCB and TOC were composited in the same sample jar for each site. The same spatula was used for all three sub-samples at a given site; however, a clean, new spatula was used at each of the seven sites listed here. A new spatula was also used for the field blank sediment. All eight newly purchased stainless steel spatulas were washed in Liquinox®

soap solution, rinsed with deionized water, and air-dried before going to the field. All were then sealed in new zip-lock bags to prevent contamination.

Each PCB and TOC sample was analyzed by Test America Labs, which is one of the contract laboratories to the USGS National Water Quality Laboratory in Denver, Colorado. Samples were chilled in coolers and shipped overnight by FedEx to Test America Labs. PCB analyses were performed for a suite of 209 PCB congeners using EPA Method 1668A[3]. Each sample was also analyzed for Total Organic Carbon (TOC) following EPA Method 9060, which is part of EPA SW846 methodology for solids analysis, and for total moisture content.

Site #1: Alameda Pump Station (latitude: N35 11' 46.2"/longitude: W106 38' 29.6"; see Photo 1 for location). Sediment was collected in the outfall channel adjacent to the Rio Grande. The sample site is approximately 50 feet downstream, or toward the Rio Grande, of a concrete stilling basin where the storm pump discharge pipe emerges from the ground. The outfall channel parallels the Alameda Boulevard bridge and is directly under the south bridge deck overhang.

Photo 1. Alameda Pump Station

Site #2: Paseo del Norte Pump Station (latitude: N35 10' 36.9"/longitude: W106 39' 6.6"; see Photo 2 for location). Sediment was collected from the storm pump outflow channel in the Rio Grande Bosque at a point near the river. This channel flows for approximately 1/2 mile through the Bosque from the storm pump discharge point before intercepting the Rio Grande. The sediment sample was taken about 50 feet from the Rio Grande and at the same location of the USGS-installed crest-stage gage.

Site #3: Adobe Acres Pump Station (latitude: N35 00' 59.5"/longitude: W106 41' 8.2"; see Photo 3 for location). Sediment was collected from the earthen-lined channel immediately upstream of the sump basin. The storm pump at this location discharges directly into a river-side drainage ditch, so a composite sediment sample was taken from sediment accumulations

immediately upstream of the storm-pump sump. The grassy channel did have small amounts of standing water at the time of sampling and was characterized as very black-colored material.

Photo 2. Paseo del Norte Pump Station

Photo 3. Adobe Acres Pump Station

Site #4: Sanchez Farms Station - Concrete Inlet Structure (latitude: N35 03' 4.2"/longitude: W106 40' 13.5"; see Photo 4 for location). Sediment was collected from the concrete inlet box upstream of the sediment settling ponds. The entire structure is approximately 20 feet wide by

30 feet long and 7 feet high. It is a man-made structure designed to catch the initial street sediment and debris runoff. The sediment was characterized as a moist, highly organic material at the time of sampling.

Site #5: Sanchez Farms Station – Inflow to Storm Pump (latitude: N35 02' 55.3"/longitude: W106 40' 15.7"; see Photo 4 for location). Sediment was collected from the grassy wetlands area immediately upstream of the storm pump structure and below the final sediment settling pond. The sediments were tan-colored, drier, and appeared to contain less organic material (not as black-colored) than the inlet structure sediments. The three subsamples were collected at locations about 10 feet apart and in a cross-sectional pattern to the flow path.

Site #6: Sanchez Farms Station – Outflow Pipe (Latitude: N35 02' 50.9" Longitude: W106 39' 54.8" see Photo 4 for location). Sediment was collected from the area immediately adjacent to the pump outflow pipe located in the Rio Grande Bosque floodplain. The discharge pipe is covered by a rubber baffle and a slight depression exists around this pipe where water obviously ponds after a flow event. The samples were taken within approximately a ten-foot radius around the discharge structure in the depression.

Photo 4. Sanchez Farm Stormwater Facility

Site #7: Embudo Canyon detention dam (latitude: N35 05' 53.3"/longitude: W106 28' 26.0"; see Photo 5 for location). Sediment from within the holding pond of the dam structure represent background conditions of PCB's in sediments in the Albuquerque area. The samples were taken in the most undisturbed area possible, away from any obvious foot or animal trails, approximately 20 feet upstream of the riser pipe in the bottom of the basin.

Photo 5: Embudo Canyon Basin

RESULTS AND DISCUSSION

Prior to analyzing Bernalillo County sediment samples, Test America Labs analyzed known samples of various PCB aroclors to produce congener spectra (i.e. relative weight percentages of congeners) for comparison with sediment analyses. Figure 2 illustrates how congener spectra are unique to specific Aroclors produced by Mansanto Corporation. The reference spectra were visually compared with PCB congener spectra in environmental samples to preliminarily assess the presence of known Aroclors, but no more detailed spectral comparisons were done.

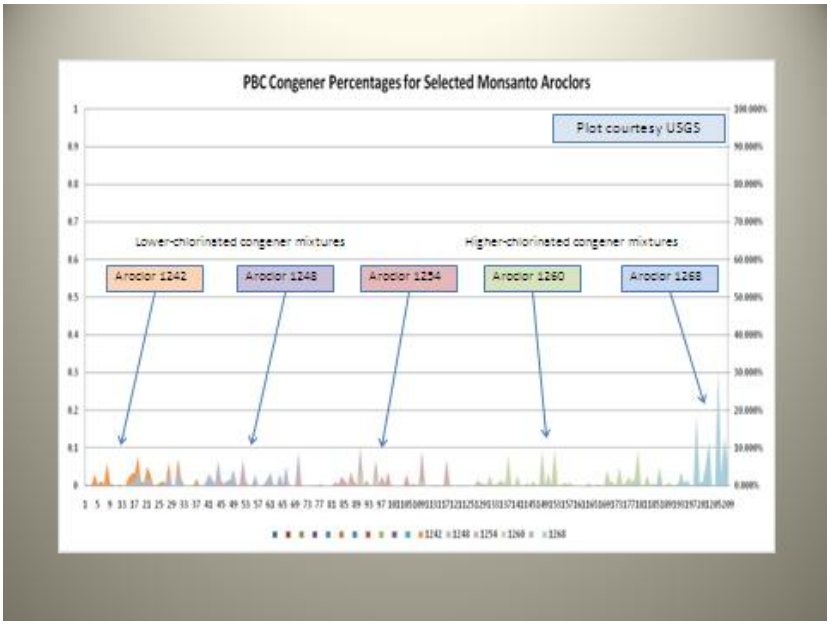


Figure 2. Congener Spectra for Certain PCB Aroclors

Analysis of the NMSLD PCB-free soil field blank using the EPA 1668A method, which is several orders of magnitude more sensitive than the Aroclor method used by NMSLD, revealed the existence of PCB congeners at 6,490 picogram per gram dry weight (pg/dry g), with an apparent predominance of Aroclor 1254 (Figure 3). It is unknown if the soil actually contained the Aroclor or if the detection is the result of a laboratory contaminant.

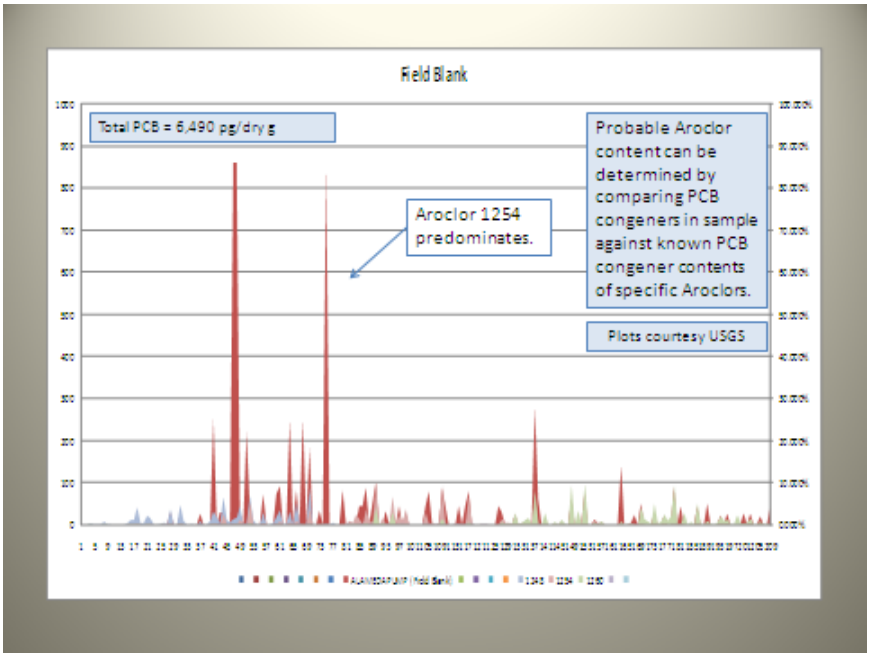


Figure 3. PCB Content of NMSLD "PCB-Free" Field Blank Soil

Analysis of the soil sample from Embudo Canyon Basin control location yielded PCB results notably similar to those observed in the field blank (Figure 4). PCBs were present at 4,874 pg/dry g, with an apparent predominance of Aroclor 1254. Comparison of the Embudo Canyon soil and the field blank soil suggests the possibility that these PCB detections may be a laboratory artifact, although more investigation is needed to confirm this conjecture.

Sediment collected from the discharge channel at the Alameda Pump Station exhibited PCBs at 57,998 pg/dry g, with apparently equivalent proportions of Aroclor 1254 and Aroclor 1260 (Figure 5). The Alameda Pump Station drains a 16-acre segment of Alameda Boulevard in north central Bernalillo County, and provides no sediment removal best management practices aside from a small detention basin at the pump station discharge point (see Photo 1).

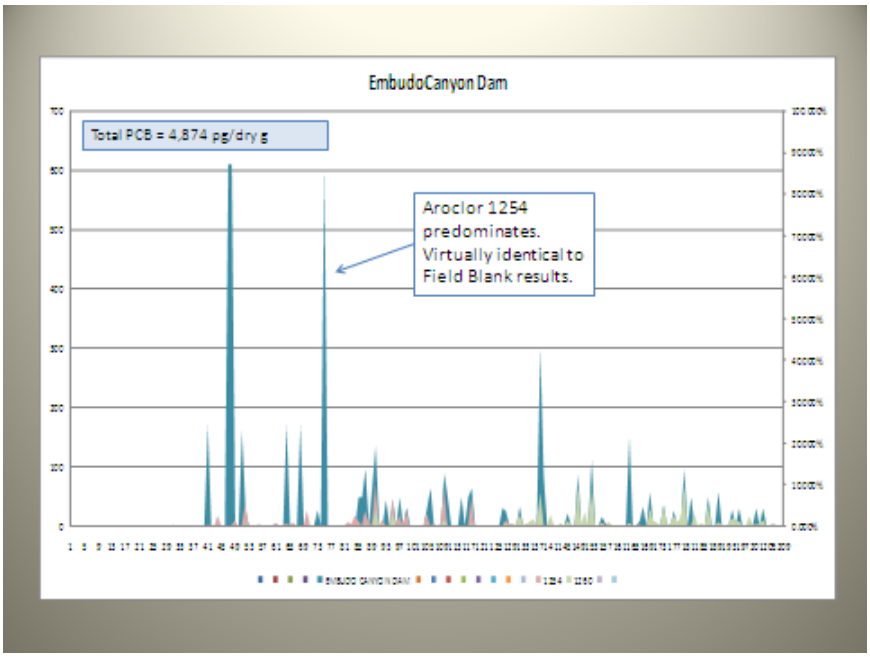


Figure 4. PCB Content of Soil from Embudo Canyon Control Location

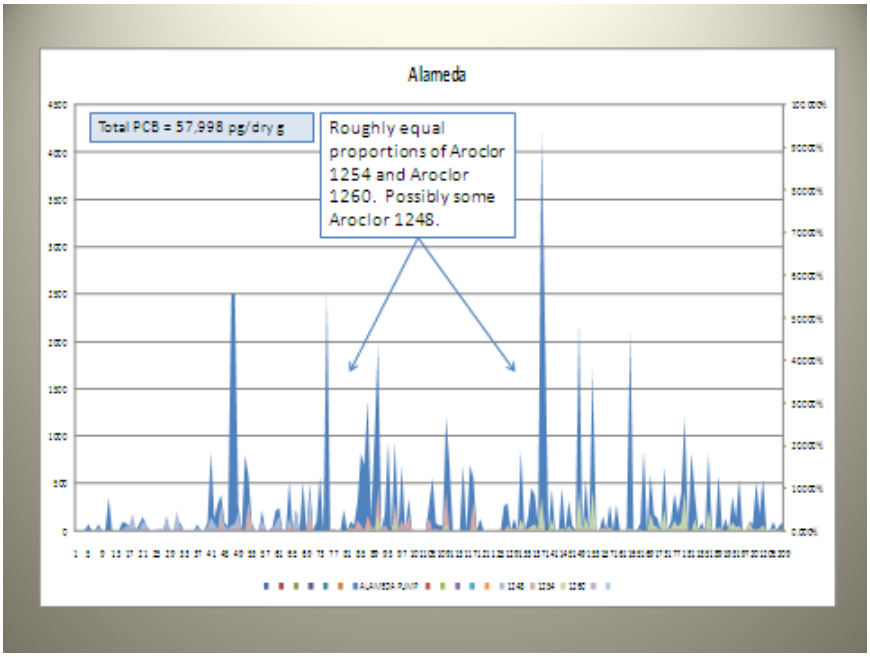


Figure 5. PCB Content of Sediment from Alameda Discharge

Sediment collected from the Adobe Acres Pump Station inlet structure contained PCBs at 62,704 pg/dry g, with apparently equivalent proportions of Aroclor 1254 and Aroclor 1260 (Figure 6). The Adobe Acres facility drains a mixed residential and commercial neighborhood of approximately 178 acres north of the pump station, and a portion of the runoff is filtered through a linear grassy swale before being discharged to the pump station (see Photo 2).

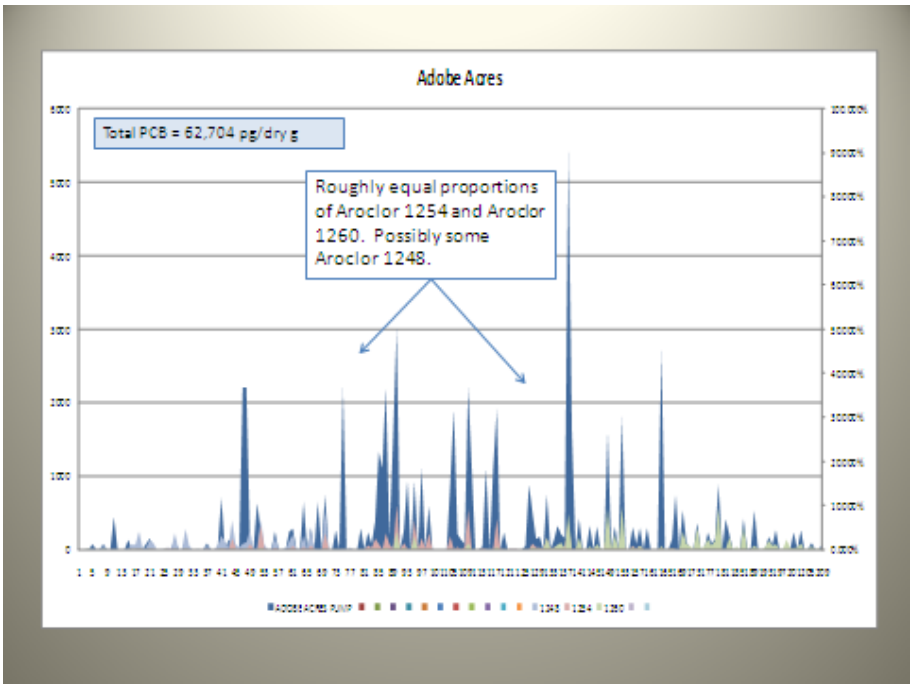


Figure 6. PCB Content of Sediment from Adobe Acres Inlet

Sediment collected from the Paseo del Norte pump station discharge channel contained 23,500 pg/dry g total PCBs, with a predominance of Aroclor 1260 (Figure 7). The Paseo del Norte pump station drains an 18-acre segment of Paseo del Norte Boulevard, and discharges to natural channel approximately 0.5 miles in length that eventually drains to the Rio Grande (Photo 3).

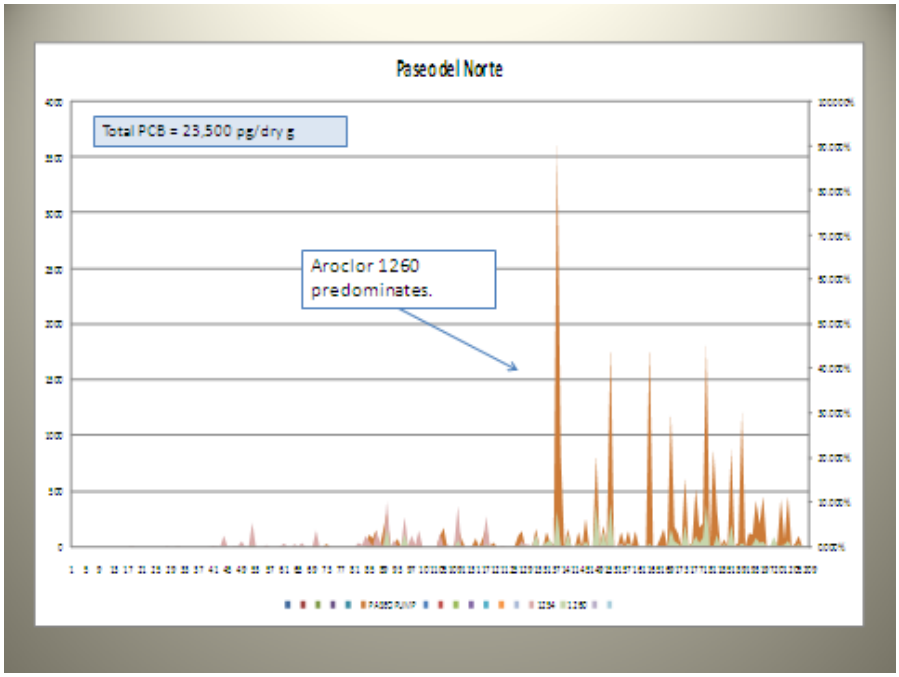


Figure 7. PCB Content of Sediment from Paseo del Norte Discharge

Sediment collected from the point of discharge from the Sanchez Farm stormwater facility contained 12,466 pg/dry g total PCBs, with a predominance of Aroclor 1260 (Figure 8). The Sanchez Farm facility drains a mixed residential and commercial watershed of over 600 acres. Stormwater is first detained in a trash and sediment removal basin, then processed through a constructed wetland before reaching the pump station for discharge to the riparian forest floor adjacent to the Rio Grande (Photo 4).

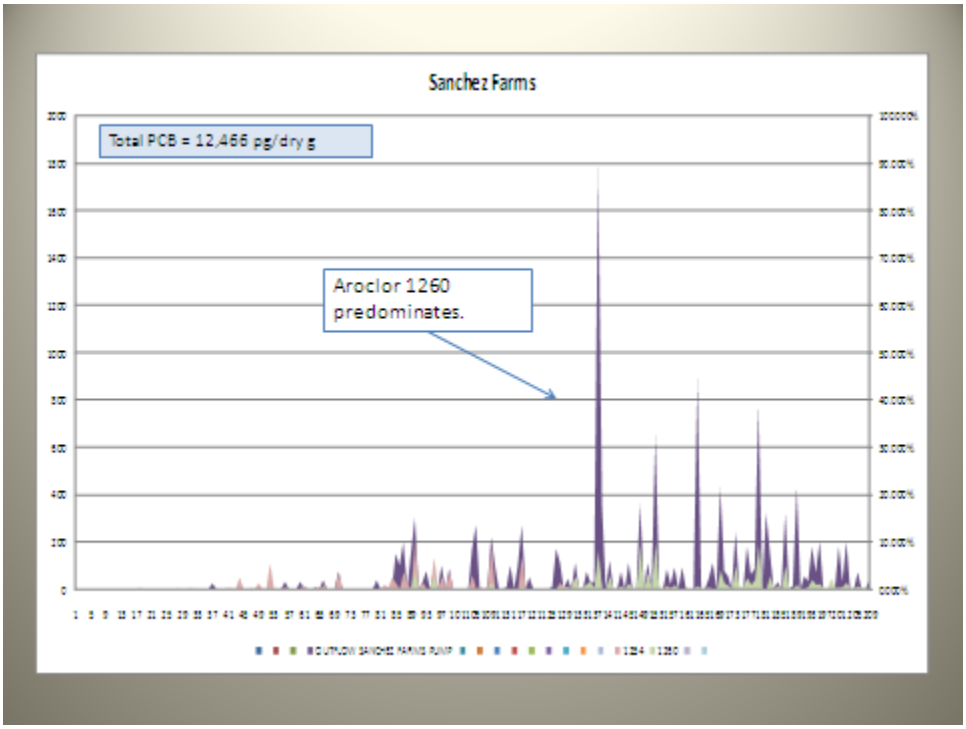


Figure 8. PCB Content of Sediment from Sanchez Farms Discharge

Table 2 summarizes all results from Bernalillo County stormwater discharge points from the 2010 study. It is notable that sediment collected from the Sanchez Farm discharge point contained PCB concentrations 47-80% lower than sediments collected from the other three Bernalillo County stormwater discharge points. Previous monitoring, conducted since 2004 by Bernalillo County in cooperation with USGS, has demonstrated that stormwater collected after treatment at the Sanchez Farm facility contains 49-81% lower concentrations of several pollutants, compared to stormwater collected at the Adobe Acres pump station. Some of the pollutants monitored since 2004, and their respective percent 6differences between the two sites, include fecal coliform (73%), total suspended solids (81%), chemical oxygen demand (51%), nitrate nitrogen (56%), ammonia nitrogen (73%), phosphorus (52%), and lead (49%). For PCBs in sediment the percent difference between the Sanchez Farm and Adobe Acres facilities was 80%.

While not a direct comparison between influent and effluent stormwater concentrations, comparisons between stormwater and stormwater sediment pollutant concentrations at the Sanchez Farm and the Adobe Acres facilities suggests a range of removal efficiency for stormwater pollutants by the BMPs installed at the Sanchez Farm facility. Comparison of stormwater and stormwater sediment quality from these two facilities is supported by the similarity of land use (mixed residential and commercial) between the two watersheds.

PCBs in Sediment at Bernalillo County Stormwater Outflows

Sample Location	Sediment Moisture (%)	Total Organic Carbon (mg/dry g)	Total PCBs (pg/dry g)	Probable Aroclors* Detected
Field Blank	0.28	2.7	6,490	1254, 1260
Embudo Canyon	0.75	11	4,874	1254, 1260
Adobe Acres Inlet	58	131	62,704	1254, 1260 (1248?)
Alameda Outflow	30	101	57,998	1254, 1260 (1248?)
Paseo del Norte Outflow	11	21	23,500	1254, 1260
Sanchez Farms Outflow	19	14	12,466	1254, 1260

* Aroclors are specific combinations of PCB congeners produced and distributed by Monsanto Company

Table 2. Summary of 2010 Bernalillo County Stormwater Sediment Results

Table 3 provides a correlation between averaged PCB results obtained by NMED during the 2009 study of Rio Grande water and by Bernalillo County during the 2010 study of stormwater sediments. NMED analyzed total water and sediment in river water for PCBs and for suspended solids concentration (SSC). Using these results, and assuming that PCBs preferentially adhere to suspended solids in the water environment, the average concentration of PCBs in sediment was computed for the NMED samples.

Bernalillo County analyzed PCB concentrations in stormwater sediments. As previously described, the County has monitored total suspended solids (TSS) in stormwater from each of its four stormwater pump stations since 2004. In Table 3, the average TSS in stormwater from each of the Bernalillo County pump stations is shown and was used with PCB concentrations in sediments to compute the estimated average PCB concentration in stormwater from each pump station.

Recognizing that hydrophobic PCBs preferentially adhere to solids in the aqueous environment, it is most appropriate to compare PCB concentrations in sediments between the NMED and Bernalillo County studies. As illustrated in Table 3, results from the two studies are comparable, at least in order of magnitude. Examining the data as a whole, it can be estimated that stormwater-borne sediments leaving the Albuquerque/Bernalillo County watershed contain 10^4-10^5 pg/dry g PCBs. Depending on the concentration of suspended solids, stormwater draining from the watershed can be estimated to contain 10^3-10^5 pg/L of PCBs. It is notable that the New Mexico Water Quality Commission (NMWQCC) has established water quality criteria for PCBs of 640 pg/L ($10^{2.8}$ pg/L) for human health and 14,000 pg/L ($10^{4.2}$ pg/L) in New Mexico waters. From Table 3, it can be surmised that only stormwater discharged from the Sanchez Farm facility

complies with any NMWQCC water quality criteria, and then only with the less stringent aquatic life criterion.

NMED vs. BC: Stormwater PCB Discharges

Sample Location	PCB in Sediment (pg/dry g)	Average SSC (mg/L)	PCB in Water (pg/L)
NMED: Rio Grande above Alameda	93,184*	1,361	142,695
BC: Adobe Acres Inflow	62,704	740‡	46,401†
BC: Alameda Outflow	57,998	558‡	32,363†
BC: Paseo del Norte Outflow	23,500	730‡	17,155†
BC: Sanchez Farms Outflow	12,466	146‡	1,820†

* PCB concentration in sediment was computed from PCB in water and SSC (NMED)
‡ Average SSC for outflows was determined from 2004-2009 sampling history (County)
† PCB concentration in water was computed from PCB in sediment and average SSC (County)
Sanchez Farms outflow follows treatment by sedimentation and wetlands

NMWQCC Human Health/Domestic Supply Criterion for PCB in Water = 640 pg/L
NMWQCC Aquatic Life Criterion for PCB in Water = 14,000 pg/L
USEPA Limit for Human PCB Exposure = 50,000,000 pg/g (40CFR761.20)

Table 3. Correlation of NMED and Bernalillo County PCB Results

Evaluating the PCB Aroclors present in Bernalillo County stormwater sediments (Table 2), and comparing with known historical uses for PCBs (Table 1), it can be surmised that PCB sources within the Albuquerque/Bernalillo County watershed are likely ubiquitous and widespread. The predominance of Aroclors 1254 and 1260 in Bernalillo County stormwater sediments suggests that PCB sources within the watershed may have been deposited prior to 1950 and are migrating slowly toward the Rio Grande. This situation makes control and elimination of PCB sources in stormwater extremely challenging.

Because hydrophobic PCBs preferentially adhere to suspended solids in the aqueous environment, removal of suspended solids should be an effective means of reducing PCB discharges in stormwater. As discussed above, long-term monitoring by Bernalillo County has suggested that the BMPs installed at the Sanchez Farm facility effectively remove stormwater pollutants including suspended solids. To directly evaluate the effectiveness of Sanchez Farm BMP for removing PCBs from stormwater, sediment samples were collected from the trash and sediment removal structure, from the constructed wetlands and from the pump station discharge point at Sanchez Farms and analyzed for PCB concentrations. Results are illustrated in Figures 9-11 and in Table 4.

Sediment from the trash and sediment removal structure contained totlal PCBs at 591,846 pg/dry g with roughly equal proportions of Aroclors 1254 and 1260 (Figure 9). Sediments form the constructed wetlands contained total PCBs at 11,212 pg/dry g with a larger proportion of Arocolr 1260 than of Aroclor 1254 (Figure 10). Finally, sediment from the pump station discharge point contained total PCBs at 12,466 pg/dry g, with a clear predominance of Aroclor 1260 (Figure 11).

Apparent PCB reduction efficiency through the Sanchez Farm facility was 98%, and there is some tentative evidence for preferential degradation of Aroclor 1254 in the constructed wetlands.

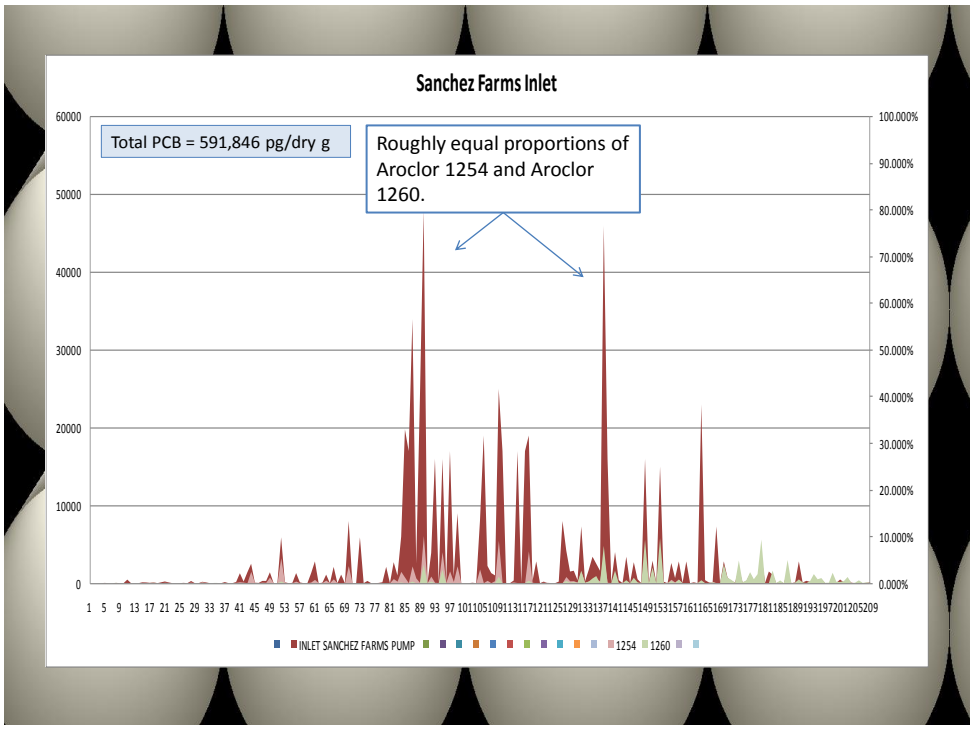


Figure 9. PCB Content of Sediments from Sanchez Farm Inlet Structure

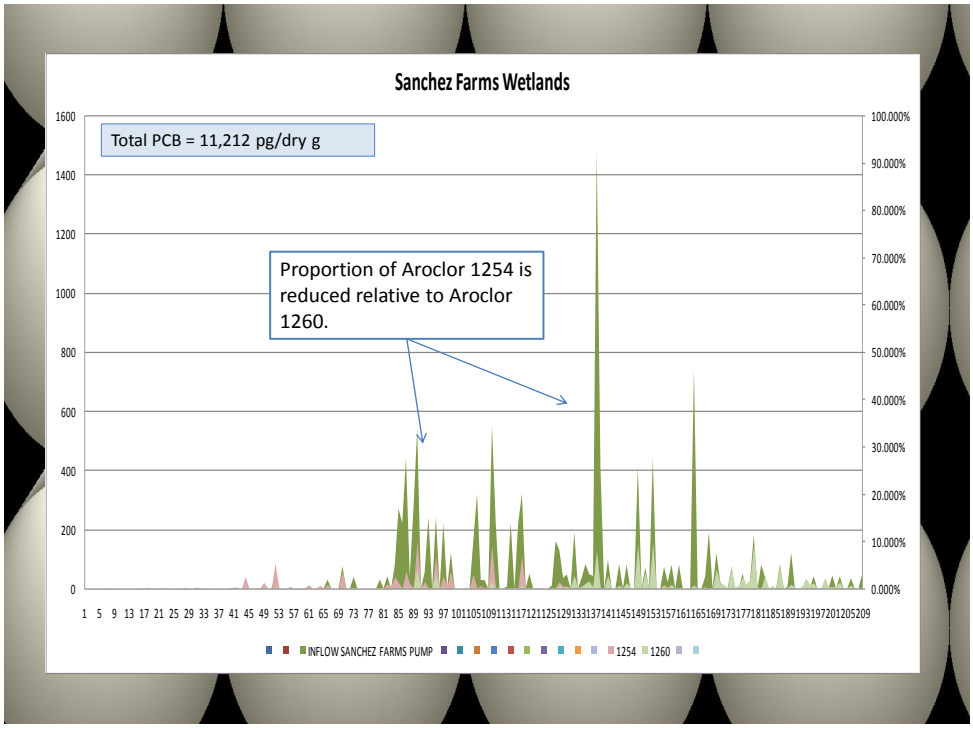


Figure 10. PCB Content of Sediments from Sanchez Farm Wetland

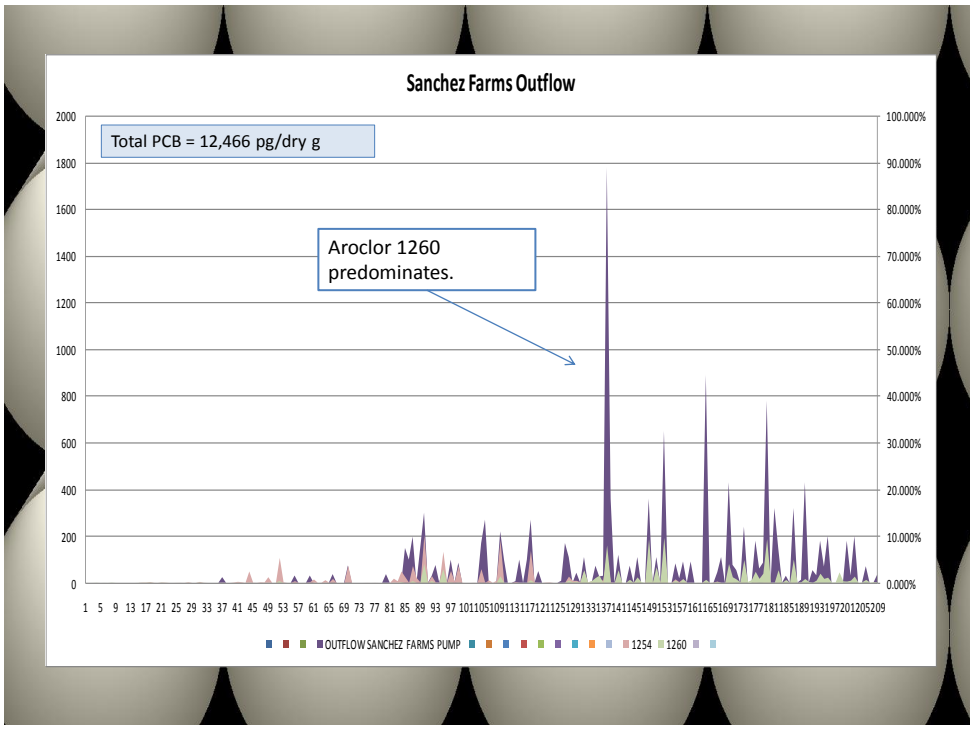
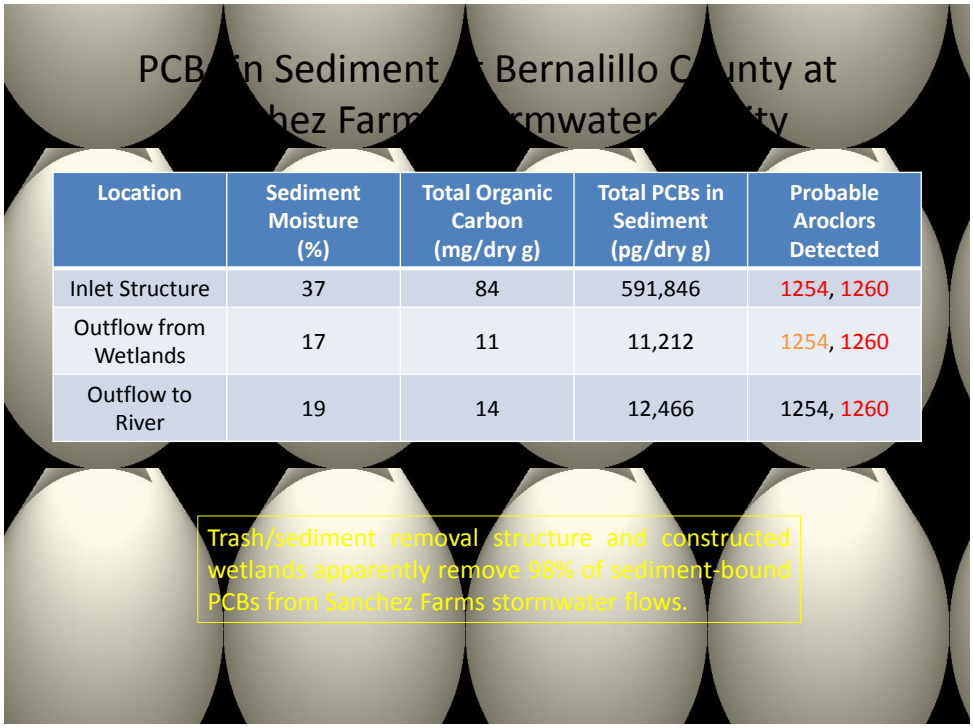


Figure 11. PCB Content of Sediment from Sanchez Farm Discharge



Location	Sediment Moisture (%)	Total Organic Carbon (mg/dry g)	Total PCBs in Sediment (pg/dry g)	Probable Aroclors Detected
Inlet Structure	37	84	591,846	1254, 1260
Outflow from Wetlands	17	11	11,212	1254, 1260
Outflow to River	19	14	12,466	1254, 1260

Table 4. Summary of PCB Contents of Sanchez Farm Sediments

PCB adherence to suspended solids in the aqueous environment is a function of the degree of organic material in the sediment, because organic matter provides necessary chemical binding sites. To explore the relationship between organic matter and PCB content in Bernalillo County

stormwater sediments, PCB concentration was plotted as a function of TOC concentration for all sediments analyzed during the 2010 Bernalillo County study (Figure 12).

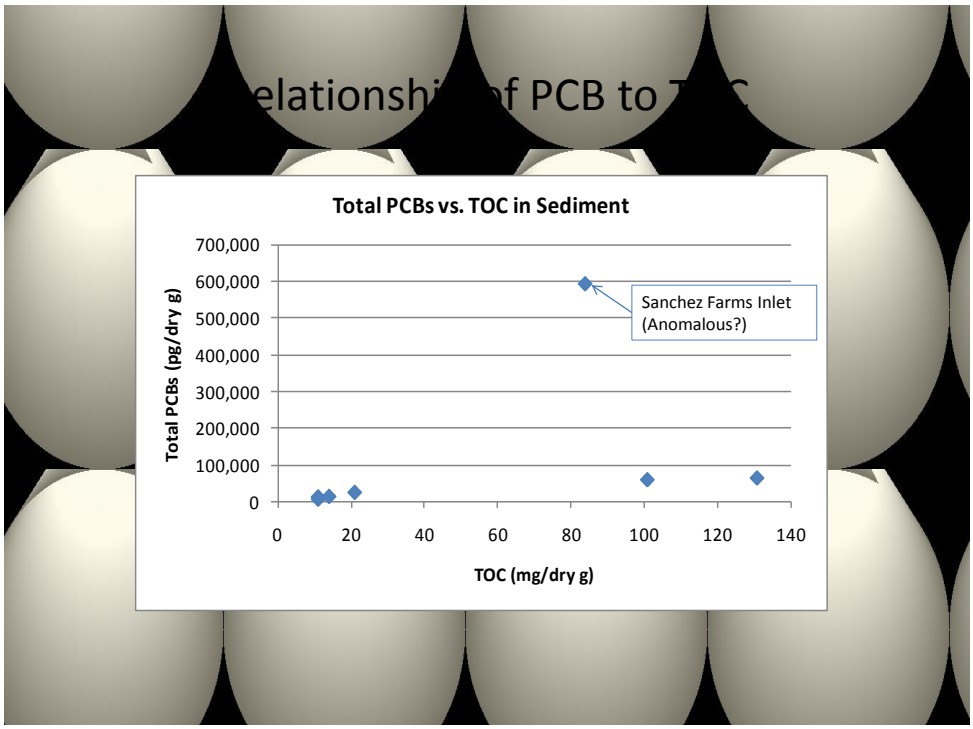


Figure 12. PCB vs. TOC Content in Bernalillo County Sediments

Initial examination of the plot revealed little obvious correlation. However, because the PCB concentration from the Sanchez Farm inlet sediment was anomalously high compared to other stormwater sediment samples, the Sanchez Farm inlet data was removed and the plot was regenerated. As shown in Figure 13, when the anomalously high Sanchez Farm inlet PCB results are excluded, a reasonable relationship between TOC and PCB concentrations is observed. A comparison of Figures 12 and 13 suggests that the sediments collected from the Sanchez Farm inlet structure may have been compromised during collection, transportation or analysis, resulting in an erroneously elevated PCB concentration. When the target analyte is detected at picogram (10^{-12} gram) levels, very small contamination levels can have large effects on apparent concentrations in sediment. Bernalillo County has funded a repeat study of Sanchez Farm sediments during 2011 to validate or correct the results observed in 2010.

CONCLUSIONS AND FUTURE DIRECTIONS

From Table 3, it is apparent that Bernalillo County results for PCBs in stormwater sediments correlate fairly well with NMED results for PCBs in whole stormwater. Results indicate that stormwater discharged from the Albuquerque/Bernalillo County watershed contains PCBs in the range of $10^3 – 10^5$ pg/dry g of suspended solids, exceeding NMWQCC water quality criteria for PCBs in New Mexico waters. Aroclors observed in Bernalillo County stormwater sediments (Table 2) suggest that PCBs leaching from the watershed were likely deposited prior to 1950 via a wide variety of PCB applications (Table 1), meaning that discovery of discrete concentrated sources of PCBs in the watershed is unlikely. Because PCBs are closely associated with organic sediments (Figure 13), reducing sediment in stormwater offers a viable approach to reducing

PCB discharges from the watershed. Table 4 illustrates the effectiveness of sedimentation and wetlands filtration in PCB removal from stormwater, but reducing sediment sources in the watershed is likely to be a more effective long-term strategy.

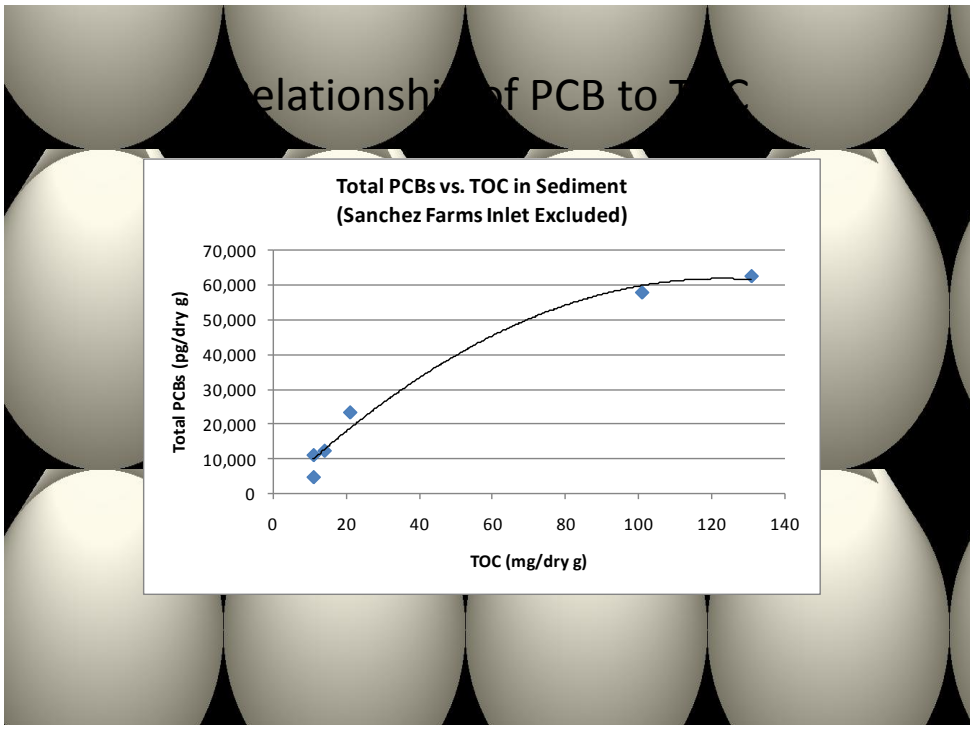


Figure 13. Censored PCB vs. TOC Content in Bernalillo County Sediments

Bernalillo County continues to pursue the issue of stormwater-borne PCBs. A repeat soils survey was conducted at the Sanchez Farm stormwater facility in May 2011. Objectives of the repeat soils survey are to confirm or correct the high PCB concentrations observed in raw sediment; to re-evaluate PCB removal rates by the sedimentation structure and the wetlands at Sanchez Farm; to re-examine PCB concentrations in sediments discharged from Sanchez Farm; and to add to the dataset from which the relationship between PCB and TOC in stormwater sediments is derived (Figures 12 and 13).

Bernalillo County, in cooperation with the Ciudad Soil and Water Conservation District, has acquired federal grant funds through the USEPA Clean Water Act 319(h) Program to conduct an engineering evaluation of BMPs applicable to County stormwater systems and state grant funds through the NM Water Trust Board to partially fund installation of one structural BMP identified in the engineering evaluation.

REFERENCES

[1]NM Environment Department, DOE Oversight Bureau. March 2010. "Storm Water Monitoring along the Rio Grande and Chama River New Mexico Conducted by NMED/DOE Oversight Bureau for FFY 2009-Q4."

[2]Wong, C.S, P.D. Capel and L.H. Nowell. September 2000. "Organochlorine Pesticides and PCBs in Stream Sediment and Aquatic Biota – Initial Results from the National Water Quality Assessment Program 1992-1995." US Geological Survey Water Resources Investigation Report 00-4053.

[3]US Environmental Protection Agency. August 2003. "Method 1668, Revision A. Chlorinated Biphenyl Congeners in Water, Soil, Sediment, Biosolids and Tissue by HRGC/HRMS." EPA-821-R-07-004.