# *Data Evaluation*

Further data analysis is intended to answer the primary questions of the study, namely:

- Are PCBs lost to the atmosphere during sediment processing, and if so, approximately how much was lost?
- Is there an increase in air risks associated with the remediation of PCB containing sediments by dredging, and if so, what is the extent of this increase?
- Are air impacts significant enough to require incorporation of air monitoring in further dredging projects?

Evaluation of the data is complicated by the documented presence of PCBs in the atmosphere before dredging commenced. Evaluation of the project associated results against the current and historic results obtained through the Wisconsin Urban Air Toxics Monitoring program is included to help answer these questions.

## Historic WUATM Data

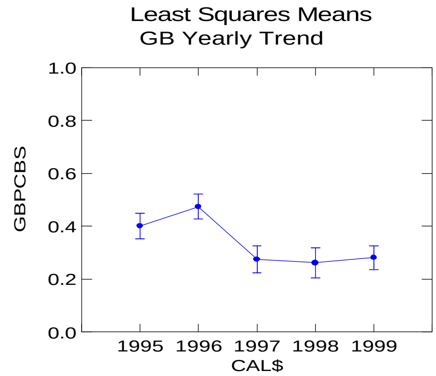
PCB monitoring has been a part of the Wisconsin Urban Air Toxics Monitoring (WUATM) program since its inception in 1991. Consistent detection of ambient PCBs in Green Bay has occurred since 1995. The results obtained since that time have ranged from <0.05 to 2.1 ng/m$^3$. Results from the Green Bay WUATM site during the project ranged from ≈0.1 to 0.5 ng/m$^3$, which is well within the historic range.

Results were further evaluated on the basis of yearly and seasonal differences to compare the current data with previous results more conclusively. In each case, results were subjected to ANOVA analysis using SYSTAT statistical software. Data is grouped according to calendar year and season of sampling. Seasons in this case are winter (December through February), spring (March through May), summer (June through August) and autumn (September through November).

Results of these evaluations are presented both graphically and in tables. Parameters include the Least Squares Mean and Standard Error of the results, along with the number of samples. Project specific means and sample quantities are included for comparison. Note that project results are not significantly different from yearly results obtained between 1997 and 1999.

**Table EV-1: Yearly Green Bay WUATM PCBs**

| Year | LS Mean | SE | Samples | Project | Samples |
|---|---|---|---|---|---|
| **1995** | 0.40 | 0.05 | 28 | | |
| **1996** | 0.47 | 0.05 | 29 | | |
| **1997** | 0.28 | 0.05 | 25 | | |
| **1998** | 0.26 | 0.06 | 20 | | |
| **1999** | 0.28 | 0.04 | 32 | **0.29** | **19** |



# *Data Evaluation*

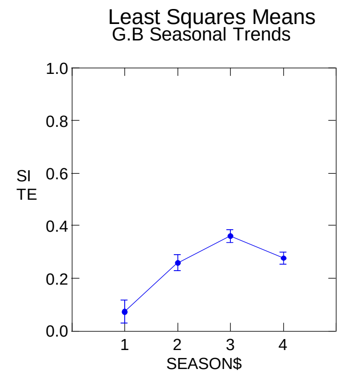
Note also that the averages obtained through 1996 are statistically indistinguishable. Samples through the first half of 1997 were obtained from the former Fox River HAP station, located within 15 meters of the waterfront, while the current site is about 850 meters from the river. The difference between averages from 1995 and 1996 and 1997 through 1999 are statistically different, revealing an apparent difference between the two sites.

Previous evaluation of data collected in the course of the WUATM program reveals a significant seasonal trend to ambient PCB concentrations. Ambient levels observed during the summer average six times higher than those during the winter, at which time the results approach the regional background levels obtained in remote sampling studies conducted by the EPA and other research groups.

The following table and graph documents WUATM and project only averages on seasonal basis. Note that results obtained prior to dredging are essentially identical to the overall seasonal least squares mean, while the autumn and winter samples (collected during dredging) appear slightly higher. Closer evaluation of the differences using a t-test assuming unequal variance indicates that these sets of data are also indistinguishable.

**Table EV-2: Seasonal Green Bay WUATM PCBs**

| Season | LS Mean | SE | Samples | Project | SE | Samples |
|---|---|---|---|---|---|---|
| Winter | 0.06 | 0.06 | 7 | 0.11 | 0.07 | 2 |
| Spring | 0.26 | 0.03 | 14 | | | |
| Summer | 0.36 | 0.03 | 18 | 0.37 | 0.05 | 4 |
| Autumn | 0.25 | 0.04 | 11 | 0.30 | 0.03 | 13 |




Several conclusions can be drawn from these evaluations:

1. The remediation project had no apparent affect on ambient PCB concentrations at the WUATM site, located approximately 3700 meters from the sediment processing area.

2. The WUATM data provides a consistent urban background observed over a period of several years. This background concentration provides a tool for evaluating impacts and increased rick associated with the remediation project.

3. Comparison of data obtained from the different WUATM sites suggests a tendency of increasing concentrations with decreasing distance from the river.

4. Seasonal trends may affect the data collected during the course of this project.

# *Data Evaluation*

**Main Study Extent of Observed Impact**

It is apparent from the tables in the Results Discussion that there are losses associated with the remediation process. Spatial analysis of pollutant dispersal from a source is complicated by many factors, including distance from and orientation to source, wind speed and direction, ambient temperature, and the topography and existence of other sources in the area.

The intent of this section is to investigate the probable extent of impacts associated with the remediation project by determining which sites are statistically distinguishable from the WUATM site and therefore above the established urban background concentrations, and by evaluating the effect of distance to the source on observed ambient levels.

Distinguishing project sites from the urban background values provided by the WUATM site involved a three step process. The first step was to group the sites which had average concentrations less than or equal to the average of the GBUATM site plus two standard deviations. This separation provides a group of results which can be considered reflective of the urban background. The mean and standard deviation of these site averages was then determined.

The next step was to separate a group of intermediate concentration on the basis of their average concentrations being greater than the GBUATM average plus two standard deviations, but less than this average plus five standard deviations. This provided a group of results which are probably representative of sites with results distinguishable from the urban background, but which is not overly skewed by the sites which are obviously distinguishable. The mean and standard deviation of these site averages was then determined.

The final step involved comparing the two sets of data using a modified Student's *t* distribution for the analysis of independent samples with unequal variance and population sizes. Both the 24 hour and the 72 hour sampling sets yielded results indicating that the background sites and the potentially distinguishable sites are indeed statistically different, to a greater than 99.5% probability. All sites greater than background as determined in this way are presented in **bold face** font in table EV-3 on the following page. Note that most samplers within 1.25 kilometers during the 24 hour sampling, and within 0.75 kilometers during the 72 hour sampling are elevated above the urban background site.

Sediment processing is complex, and presents the possibility of multiple air sources. The dredging activity disturbs sediments which can increase contaminant water concentrations, which can then volatilize and result in increased air concentrations. The settling basins provide a large, shallow area with relatively concentrated PCBs, which makes them relatively major potential sources. The final processing of dried sediment can lead to release of particulate borne PCBs into the atmosphere in addition to volatile losses.

The complications introduced to spatial analysis of dispersion by the presence of multiple potential sources in evaluating impacts are simplified in this evaluation by regarding the sampler with the highest observed concentration as the central location from which distances are determined. This simplification therefore sidesteps the question of influences introduced by other sources, by concentrating on the area of highest observed impact.

These distances (in kilometers) are included in Table EV-3 below. Note that during the 24 hour sampling, the highest concentration site was FR02, while during the 72 hour sampling site FR01 reports the highest values. Potential reasons for this will be discussed in the Comparison with Process Data section. Values in parentheses represent sites which failed the minimum completeness criteria. These values are not incorporated into subsequent evaluations.

**Table EV-3: Site Averages (ng/m$^3$) and Distances (kilometers)**

| Site | 24 Hour Average | Distance | 72 Hour Average | Distance |
|---|---|---|---|---|
| **FR01** | **15.4** | 0.20 | **14.8** | 0 |
| **FR02** | **39.9** | 0 | **10.1** | 0.20 |
| **FR03** | **1.6** | 0.36 | **1.7** | 0.29 |
| **FR04** | **2.9** | 0.33 | **4.2** | 0.14 |
| **FR05** | »**0.7** | 0.28 | **0.6** | 0.29 |
| **FR06** | ≈0.3 | 0.61 | **0.5** | 0.74 |
| **FR07** | »**1.2** | 0.77 | **0.6** | 0.65 |
| **FR08** | **<1.2** | 0.78 | **<0.9** | 0.63 |
| **FR10** | »**0.8** | 0.61 | (≈0.1) | (0.80) |
| **FR11** | »**0.8** | 0.99 | 0.4 | 0.91 |
| **FR12** | »**0.6** | 1.24 | 0.3 | 1.07 |
| FR13 | ≈0.4 | 1.41 | 0.3 | 1.24 |
| FR14 | (≈0.3) | (1.53) | ≈0.2 | 1.34 |
| FR16 | ≈0.3 | 1.16 | ≈0.2 | 1.14 |
| FR17 | ≈0.4 | 0.85 | ≈0.2 | 0.98 |
| FR18 | ≈0.3 | 1.84 | ≈0.3 | 1.98 |
| FR19 | ≈0.3 | 1.88 | ≈0.2 | 2.01 |
| FR20 | ≈0.4 | 2.02 | ≈0.2 | 1.92 |
| FR21 | ≈0.3 | 2.90 | ≈0.1 | 2.75 |
| GBUATM | ≈0.3 | 3.67 | ≈0.2 | 3.72 |

The generally decreasing concentrations with increasing distance from the remediation area suggests a possible relationship that can be explored using linear regression techniques. Linear regression attempts to relate concentration to distance as a line defined by the equation: $Y = mX + b$; where $Y$ = ng/m$^3$, $m$ = slope of the line, $X$ = distance, and $b$ = the intercept of the line.

However, pollutant dispersal is not a directly linear process. Assuming the absence of other factors, which this analysis does, pollutant molecules may move in any direction with equal probability, thereby implying a theoretically spherical dispersion pattern. Thus the concentration decrease may be more closely related to the volume of dispersion, than the linear distance, which represents the radius of the theoretical sphere.

# *Data Evaluation*

The volume of a sphere is determined by the equation: Volume = $4/3 \pi r^3$ ; where r is the radius. Therefore, if the approximation of a spherical dispersion pattern is valid, concentration would be expected to decrease as a function of the cube root of the distance from the source.

A number of different combinations of data have been used in an attempt to compensate for the very steep initial decrease and more gradual later decrease. These combinations are based on choosing different maximum or minimum distances for input to the regression calculations.

Table EV-4 below presents the regression statistics generated from these determinations. The regression parameters reported include slope (how steep the line is), intercept (what the predicted concentration at zero distance is), and $R^2$ (a statistical factor measuring how well the data fits the line). The slope of this data is negative, representing the decrease in concentration ($ng/m^3$) per kilometer distance from the highest concentration sampler.

The intercept of the line should approximate the highest site average, since it is considered the zero distance point. The closer to the observed value the calculated intercept is, the more reliable the concentration/distance relationship becomes. The closest values are reported in **bold face** in the table below.

An ideal line (Y = mX + b) would have an $R^2$ value of 1.0, indicating that 100% of the variation in Y values is explained by differences in X. Data which returns an $R^2$ value of greater than 0.7 is considered acceptably linear and indicative of a strong relationship between the parameters being evaluated. It is important to keep in mind that only distance of the sampler from the central site is being considered in these equations, with such factors as orientation and wind direction being ignored. All $R^2$ values greater than 0.7 are in **bold face** below.

**Table EV-4: Regression Statistics**

| **Concentration vs distance^$^{1/3}$** | **24 Hour** | | | **72 Hour** | | |
|---|---|---|---|---|---|---|
| | **Slope** | **Intercept** | **$R^2$** | **Slope** | **Intercept** | **$R^2$** |
| **All** | -20.4 | 23.1 | 0.521 | -8.7 | 10.2 | 0.572 |
| **<1250 M** | -37.9 | 35.3 | **0.773** | -14.4 | 14.0 | **0.762** |
| **<1000 M** | -43.4 | **38.3** | **0.828** | -16.4 | **15.1** | **0.782** |
| **<750 M** | -55.3 | 43.8 | **0.916** | -18.2 | 15.9 | **0.776** |
| **<500 M** | -63.6 | 46.9 | **0.951** | -21.9 | 17.3 | **0.723** |
| **>1250 M** | -0.1 | 0.5 | 0.103 | 0.1 | 0.1 | 0.029 |
| **>1000 M** | -0.2 | 0.7 | 0.131 | -0.1 | 0.3 | 0.083 |
| **>750 M** | -1.1 | 1.8 | 0.411 | -0.2 | 0.5 | 0.227 |
| **>500 M** | -0.8 | 1.5 | 0.300 | -0.7 | 1.1 | 0.429 |
| **>200 M** | -1.6 | 2.4 | 0.375 | -1.1 | 1.6 | 0.478 |

# *Data Evaluation*

Note that with the exception of regressions constructed from all of the data or from the more distant sites only, the linearity of the impact area is good, and in some cases, exceptional. The main implication of this observation is that the results of this study are reasonably well explained out to 1.25 kilometers by a spherical dispersion model. That there is not a good correlation between distance and concentration for the more distant sites indicates that other factors are needed to explain the differences observed between these sites.

The lines defined by the regressions with an $R^2$ greater than 0.7 are plotted in graphs on the following page (figures 4 and 5). The initial steep portion of the curves are plotted using the statistics from the top portion of the table, while the flatter portion of the curves are based on the statistics in the lower portion of the table. Each line is constructed from related sets of regression statistics (for example, the <500 slope and intercept is used from distance zero to where it intersects with the line defined by the >500 slope and intercept).

The following conclusions are apparent from the evaluations in this section:

1. Remediation activity did increase ambient PCB concentrations in the main study area.

2. During the 24 hour sampling, results from samplers located further than 1.25 kilometers from the remediation area are at or below the established background concentrations in Green Bay.

3. During the 72 hour sampling, results from samplers located further than 0.75 kilometers from the remediation area are at or below background.

4. A simplified dispersion model assuming spherical dispersion of the PCB shows that greater than 70% of the observed trends is explained by distance from the source.

**Figure 4: 24 Hour Regressions**

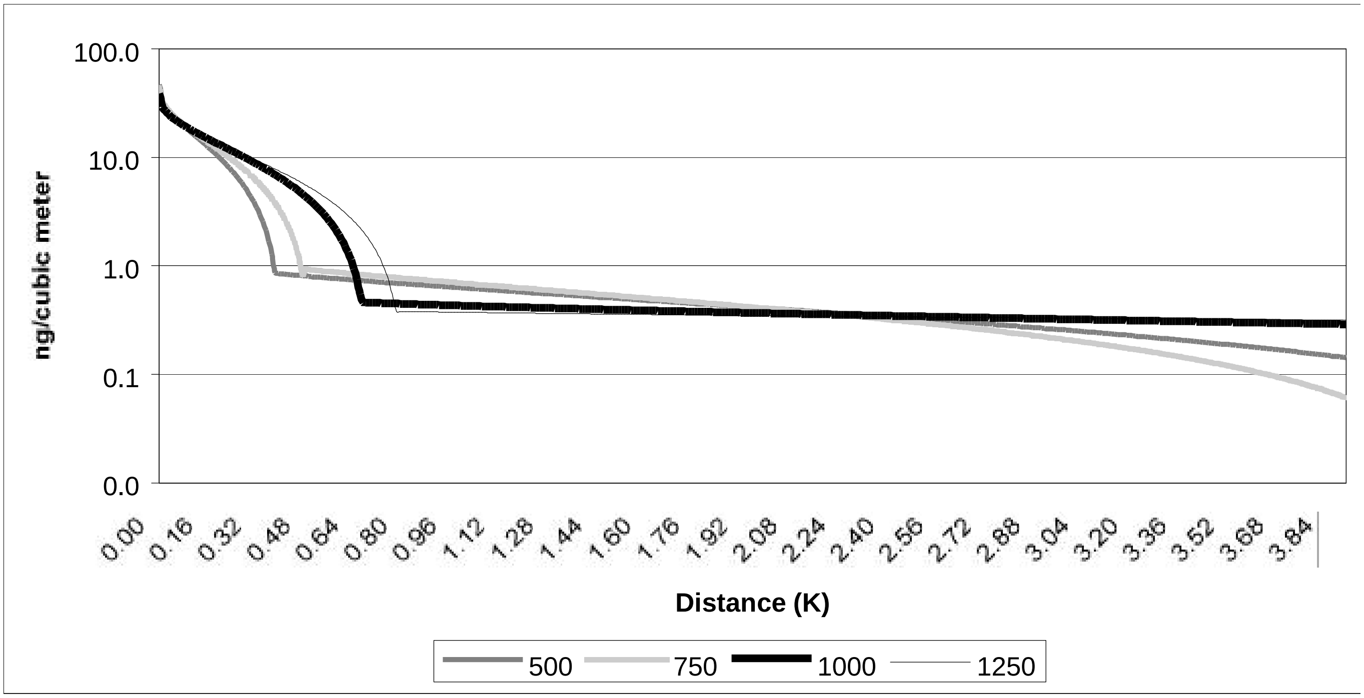
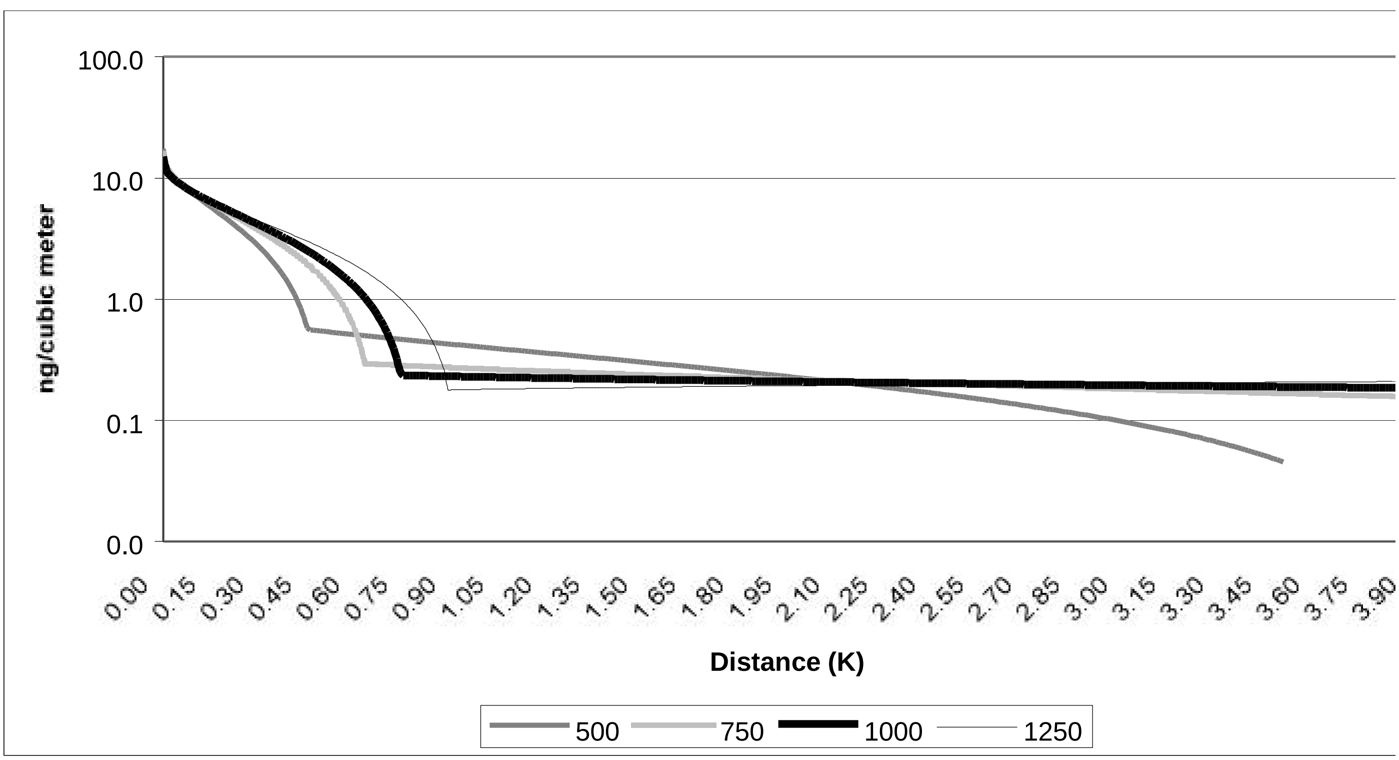



**Figure 5: 72 Hour Regressions**



# *Data Evaluation*

**Differences in Background Levels**

There are slight differences observable between the urban background site, the main project sites which are not observably affected by dredging, and the more distant sites. These differences are masked during the 24 hour sampling portion of the project, because the detection limit of these samples is about the same as the background levels. However, data collected during the 72 hour portion of the project provides sufficient information for an initial investigation of these differences.

It should be noted that most of the data being evaluated here involves results which are between the laboratory's Limit of Detection (LOD) and Limit of Quantitation (LOQ). Results within this range are generally considered estimates, rather than firm values. In addition, many of the sites incorporated into this are closer to the remediation area than to the river, which may skew the analysis. Therefore, this evaluation should be viewed as a rough estimate, and any resulting trends observed as merely suggestive.

Significant amounts of research have indicated that bodies of water containing PCB contaminated sediments may be a source to the atmosphere. This section seeks to establish whether differences in ambient PCBs between sites indistinguishable from the urban background site and the more distant sites could be related to distance from the Fox River. Site averages and distances are subjected to regression analysis as in the previous section.

Table EV-5 below presents the 72 hour site averages and distances to the river for the urban background site, the main project sites which were not observably impacted by the dredging project, the landfill sites and the two distant background sites. Results have not been rounded to one decimal place as in previous tables. Table EV-6 presents regression statistics from two separate scenarios.

**Table EV-5: Background Site Differences**

| Site | Concentration | Distance To River (K) |
|---|---|---|
| FR12 | 0.27 | 0.61 |
| FR19 | ≈0.21 | 0.61 |
| FR13 | 0.26 | 0.68 |
| FR14 | ≈0.18 | 0.84 |
| GBUATM | ≈0.23 | 0.85 |
| FR16 | ≈0.21 | 0.96 |
| FR17 | ≈0.24 | 1.26 |
| FR20 | ≈0.15 | 2.05 |
| FR18 | 0.26 | 2.21 |
| FR21 | ≈0.15 | 2.21 |
| FR22 | ≈0.11 | 9.91 |
| FR23 | <0.08 | 19.50 |
| LF02 | ≈0.16 | 7.43 |
| LF01 | ≈0.19 | 7.78 |
| LF03 | ≈0.18 | 8.46 |

**Table EV-6: Background Regressions**

| | Slope | Intercept | $R^2$ |
|---|---|---|---|
| All Sites | -0.07 | 0.29 | 0.584 |
| No LF | -0.09 | 0.31 | 0.672 |

The second scenario in the table above (No LF) disregards the landfill oriented sites on the basis that remediation activities in this area may influence concentrations. The resulting improvement in the $R^2$ value is somewhat supportive of this idea.

The $R^2$ value from the No LF scenario suggests that 2/3rds of the differences observed between sites can be explained by the distance from the Fox River.

This suggestion of a trend supports the evidence provided by comparing the urban air toxics monitoring data collected at the two different sites, as discussed in the WUATM Historic Data section above. The other set of samples which could be used to evaluate the impact of PCB volatilization from the river are those collected before dredging began. Unfortunately, there are too few samples available for realistic evaluation.

In spite of this lack of quantitative reliability, the data collected before dredging is also suggestive of the river providing a constant source of PCB to the atmosphere. Results of each sampling event are tabulated below, with sampler distances from the river included. Performing a linear regression with these results yields an $R^2$ of 0.807. An $R^2$ of this magnitude would usually imply the certainty of a strong linear relationship; however, the nature of the data used (single samples) requires that the trend remains merely suggestive.

**Table EV-7: Pre-Dredge Samples**

| Site | 08/28/99 | 09/04/99 | Distance |
|---|---|---|---|
| FR03 | | 1.7 | 0.01 |
| FR08 | | 1.7 | 0.03 |
| FR04 | 1.0 | | 0.15 |
| FR01 | ≈0.7 | | 0.25 |
| FR02 | 0.8 | | 0.40 |
| FR19 | | 1.1 | 0.61 |
| FR13 | | ≈0.6 | 0.68 |
| FR20 | 0.4 | | 2.05 |
| FR21 | ≈0.5 | ≈0.4 | 2.21 |

Three separate sets of data (Historic WUATM, background sites, and the pre-dredge samples) each suggest that the river is a source of PCB to the atmosphere, without individually providing sufficient evidence to be entirely confident of this. However, this much independent data showing the same general trend increases the certainty of the suggestion, especially in light of the numerous studies documenting volatilization from rivers containing contaminated sediments.

The evaluations presented thus far address the question of whether PCBs are lost to the atmosphere during dredging, and allow the following conclusions to be drawn:

1) A pre-dredging background level of PCB is present in the atmosphere. While not conclusive, the data associated with this project suggests that the river itself is a probable source of the material.

2) Dredging activities increased ambient concentrations of PCB significantly above background levels up to about a kilometer away.

3) Samples obtained greater than about a kilometer away are virtually indistinguishable from the established urban background.

# *Data Evaluation*

**Risk Assessment**

Assessment of health risk associated with a project of this nature is complicated by a number of factors. A major complication for all risk assessments is the fact that each of us carries a variety of persistent pollutants in our bodies, which makes assigning risk values associated with individual compound classes difficult. Evaluating synergistic affects from multiple exposures is difficult and not well characterized.

Additionally, most such assessments are based on lifetime exposures (70 years), leaving the application of resulting risk factors open to interpretation. One approach is to use a linear extrapolation such that you simply take the ratio of time exposed vs. the 70 years (e.g., if 1 month, then figure out ratio of 1 month to 70yrs times 12 months/year – factor is 1/840 or .0012). Other evaluations attempt to factor in the susceptibility during early life stages to carcinogens due to rapid developing organisms with nervous and immune systems not quite up and running yet. The best one can do is choose a conservative approach, and recognize that there is no definite way to assess short term risks at present.

Beyond these difficulties is the fact that the atmospheric concentrations of PCBs observed during the course of this project were generated while removing sediments from the river and sequestering them in a landfill. This removal may include reductions in risk, by potentially reducing the concentrations present in the river, thereby leading to a reduction in levels observed in fish, as well as potentially decreasing local ambient levels.

Evaluations of the potential reduction in risk associated with removal of contaminated sediment will take years to determine conclusively, and is beyond the scope of this report. It is important to keep the potential reductions of risk in mind while evaluating the short term increases documented here.

With these qualifications in mind, the established EPA standard unit risk value is 1.1 X $10^{-4}$, based on a concentration of 1.0 ug/$m^3$ (1000 ng/$m^3$). This means that if someone was exposed to this concentration in air for 70 years, they would have a roughly one in 10,000 risk of developing cancer that could be attributed to this exposure. The ambient level of concern for this project was set 100 ng/$m^3$, at which concentration a 70 year exposure could be attributed to a single cancer out of 100,000 people.

At no time did concentrations observed at any location equal or exceed this value. Outside of an approximately one kilometer radius from the remediation area, concentrations were not elevated above the urban background sites, therefore representing no increase in observable risk associated with the project. Concentration based risks and increases relative to background are documented in tables EV-8 and EV-9 on the following page. All sites indistinguishable from background have been combined in these tables.

Note that although the risk factor increases by as much as 120 times over background at site FR02 (the Filter Press), it still remains below the level of 1 cancer attributable to the exposure in 100,000 people. It should also be noted that remediation personnel were required to wear environmental suits and masks while working in this area.

# *Data Evaluation*

**Table EV-8: Increases in Risk During 24 Hour Sampling**

| | Concentration | | Risk Estimate | | Risk Relative to Background | |
|---|---|---|---|---|---|---|
| **Site** | **Average** | **Max** | **Average** | **Max** | **Average** | **Max** |
| **FR02** | 39.9 | 79.7 | 4.4E-06 | 8.8E-06 | 120 | 95 |
| **FR01** | 15.5 | 28.5 | 1.7E-06 | 3.1E-06 | 47 | 34 |
| **FR04** | 2.9 | 4.3 | 3.2E-07 | 4.8E-07 | 9 | 5 |
| **FR03** | 1.6 | 3.6 | 1.8E-07 | 3.9E-07 | 5 | 4 |
| **FR08** | 1.2 | 1.9 | 1.3E-07 | 2.1E-07 | 4 | 2 |
| **FR07** | 1.2 | 2.4 | 1.3E-07 | 2.6E-07 | 4 | 3 |
| **FR09** | 1.0 | 2.5 | 1.1E-07 | 2.7E-07 | 3 | 3 |
| **FR11** | 0.8 | 1.6 | 8.9E-08 | 1.7E-07 | 2 | 2 |
| **FR10** | 0.8 | 2.1 | 8.5E-08 | 2.3E-07 | 2 | 2 |
| **FR05** | 0.7 | 1.3 | 7.2E-08 | 1.4E-07 | 2 | 2 |
| **FR12** | 0.6 | 1.0 | 7.0E-08 | 1.1E-07 | 2 | 1 |
| **Background** | 0.3 | 0.8 | 3.6E-08 | 9.2E-08 | 1 | 1 |

**Table EV-9: Increase in Risk During 72 Hour Sampling**

| | Concentration | | Risk Estimate | | Risk Relative to Background | |
|---|---|---|---|---|---|---|
| **Site** | **Average** | **Max** | **Average** | **Max** | **Average** | **Max** |
| **FR01** | 15.7 | 21.6 | 1.7E-06 | 2.4E-06 | 73 | 63 |
| **FR02** | 10.1 | 13.2 | 1.1E-06 | 1.5E-06 | 47 | 39 |
| **FR03** | 1.7 | 2.3 | 1.9E-07 | 2.6E-07 | 8 | 7 |
| **FR04** | 4.2 | 6.5 | 4.7E-07 | 7.2E-07 | 20 | 19 |
| **FR05** | 0.6 | 0.8 | 6.3E-08 | 8.9E-08 | 3 | 2 |
| **FR06** | 0.5 | 0.7 | 5.4E-08 | 7.9E-08 | 2 | 2 |
| **FR07** | 0.6 | 1.0 | 6.3E-08 | 1.1E-07 | 3 | 3 |
| **FR08** | 0.9 | 1.1 | 1.0E-07 | 1.2E-07 | 4 | 3 |
| **FR11** | 0.4 | 0.7 | 4.6E-08 | 7.2E-08 | 2 | 2 |
| **Background** | 0.2 | 0.3 | 2.4E-08 | 3.8E-08 | 1 | 1 |

To place this risk into perspective, a theoretical comparison was made between eating one half-pound white bass fillet from the river and breathing the air. This type of comparison is much more complex than indicated here, because absorption of PCBs through lung tissue and the digestive tract do not necessarily occur at the same rate. It is assumed that the fish filet weighs 250 grams, and contains 2 ppm PCB, and that the average volume of air breathed in a day is 20 cubic meters.

Eating the fish filet would theoretically expose one to 0.5 mg of PCB, a level which would be reached by breathing the general background air in Green Bay for about 228 years, air at the settling basin during the remediation for about 4.6 years, and air during the maximum observed samples at the filter presses for 312 days.