# Development of a Total Maximum Daily Load for Dioxin for the Ohio River

***Ohio River Miles 237.5 to 317***

***September 2000***

## EXECUTIVE SUMMARY

In 1997, the U.S. Environmental Protection Agency, Region 3, entered into a Federal Consent Order to complete a Total Maximum Daily Load (TMDL) for dioxin for the Ohio River by September, 2000. The Ohio River Valley Water Sanitation Commission is completing the monitoring, modeling and daily load analysis on behalf of Region 3. This effort has been coordinated and reviewed, on an ongoing basis, by the Commission's TMDL Work Group. This work group is composed of representatives from all mainstem states, and US EPA Regions 3, 4, 5 and headquarters.

TMDLs are required for waters not meeting applicable water quality standards after application of best practicable control technology. A TMDL must be designed to meet water quality standards, which is 0.013 pg/L for the Ohio River for 2,3,7,8-TCDD (dioxin). TMDLs must include allocations. TMDLs must consider background conditions, which are accounted for through the utilization of the dioxin sample data. TMDLs must consider critical conditions and seasonality, which are accounted for by utilizing harmonic mean flow (representative of a long-term average condition).

Based on West Virginia's 1998 303(d) list, a dioxin TMDL is to be completed for the Ohio River segment from Ohio River Mile (ORM) 237.5 to ORM 317. This segment borders Ohio and West Virginia. "High Volume" dioxin sampling, a collection technique that effectively concentrates 1000 liters (L) into a single sample in order to achieve necessary detection levels, was conducted within the TMDL segment during 1997-1998. Multiple samples were collected over the period at various flows. The data are used to estimate TMDL segment boundary loads and to verify water quality modeling results. The SMPTOX4 water quality model was utilized to determine dioxin loads at various river flows. The model was run at three flows: seven day-ten year low flow, harmonic mean flow, and a one-year flood high flow. These flow regimes compare reasonably with flows at which monitoring data were collected. Modeling results cannot be reliably verified at flows substantially above the one-year flood due to uncertainties that cannot be evaluated due to the absence of monitoring data at higher flows.

Based on monitoring and modeling data, the Ohio River frequently exceeds both Ohio's and West Virginia's water quality standard for dioxin within the TMDL segment at all flows evaluated. West Virginia's water quality standards apply a $10^{-6}$ CRL (0.013 pg/L for dioxin) at 7Q10 low flow, while Ohio's standards apply a $10^{-5}$ CRL (0.13 pg/L) at one-tenth harmonic mean flow (equivalent to a $10^{-6}$ CRL at harmonic mean flow).

The highest dioxin concentrations and loads in the Ohio River occur immediately downstream of the Kanawha River at ORM 266. The harmonic mean flow was selected as the appropriate critical condition for use with the dioxin stream criterion, which has been established to protect human health at a $10^{-6}$ cancer risk level over life-time exposures to ingestion of water and fish. The harmonic mean flow most accurately describes long-term flow conditions. At this flow, model results indicate a total daily maximum load of 2,3,7,8-TCDD in the Ohio River equal to

4245 ug/day. The load that would not result in stream criterion exceedances at this flow equals 1097 ug/day. Thus, a 74 percent reduction in the Ohio River dioxin load, or 3148 ug/day, is necessary. Eighty one percent of the total Ohio River dioxin load at ORM 266 is from the Kanawha River Basin and the remaining 19 percent from the upper Ohio River. Since the harmonic mean flow has been selected as the critical condition, necessary reductions are designed to meet water quality standards at this flow. This TMDL recommends that proportionate reductions in dioxin load be obtained from both the Kanawha and upper Ohio Rivers. Even though the upper Ohio River meets water quality standards at the harmonic mean flow, a 19 percent reduction (152ug/day) is being required because it contributes that proportion of the total load which does exceed standards downstream. The remaining necessary reduction of 81 percent will be required from the Kanawha River, equaling 2996 ug/day, which is 87 percent of the Kanawha dioxin loading.

Based on monitoring data and modeling results, Ohio River dioxin concentrations increase with increasing flow. At the one-year flood, modeled dioxin concentrations and loads at ORM 266 are 0.13 pg/L and 83,693 ug/day, respectively. The stream criterion and resulting load that would not cause water quality standards violations at the one-year flood flow condition are 0.013 pg/L and 8491 ug/day, respectively. Thus, Ohio River loads would need to be reduced by ninety percent to meet water quality standards at the one-year flood. At the one-year flood, 55 percent of the total dioxin loading originates within the Kanawha River Basin, while the remaining 45 percent if from the upper Ohio River Basin. It is anticipated that loadings would be even greater at higher flows.

There is no net increase of dioxin within the TMDL segment except for Kanawha River inputs, thus all important dioxin sources are located upstream of the TMDL segment. While several contaminated sites have been identified in the Kanawha Basin, no dioxin loads to surface waters within or upstream of the Ohio River TMDL segment have been identified. Potential higher flow-related sources include runoff from contaminated sites and re-suspension of contaminated bed sediments. Atmospheric deposition was eliminated as a source within the TMDL segment based on results of limited sampling, however it could be a source upstream of the TMDL segment. Results of an upper-Ohio River dioxin survey (Figure 10) suggest the possibility of sources upstream of ORM 20 and between ORM 129 and 175.

A monitoring plan to identify and quantify sources in the upper-Ohio River and to quantify loads from re-suspension of contaminated sediments is presented and will be completed during 2000-01 under the Ohio River Watershed Pollutant reduction Program.

## INTRODUCTION

Section 303(d) of the Clean Water Act requires states to develop lists of waters still requiring total maximum daily loads (TMDLs). In 1997, U.S. EPA entered into a federal Consent Agreement obligating them to complete a TMDL for dioxin on the Ohio River from ORM 266 to ORM 312, per West Virginia’s 1996 draft 303(d) List, by September, 2000. West Virginia’s 1998 303(d) List includes the Ohio River for dioxin (2,3,7,8-TCDD) from Racine Dam at Ohio River mile (ORM) 237.5 to the West Virginia state line at ORM 317. The listing was based on West Virginia fish consumption advisories and “high volume” water column sampling for dioxin conducted by the Ohio River Valley Water Sanitation Commission (ORSANCO). Hence, the requirement for the Ohio River dioxin TMDL was extended to include the segments on the 1998 list (ORM 237.5 to ORM 317).

The seven minimum regulatory requirements of a TMDL are:

1. TMDLs must be designed to meet water quality standards.
2. TMDLs must include load allocations (LAs) and wasteload allocations (WLAs). A load allocation is an allowable pollutant discharge quantity for a nonpoint source(s). A WLA is an allowable pollutant discharge quantity from a point source(s). The combined WLA and LA must not result in water quality standards violations.
3. TMDLs must consider background (natural) contributions.
4. TMDLs must consider critical conditions.
5. TMDLs must consider seasonal variations (i.e. multiple critical conditions are possible).
6. TMDLs must include a margin of safety.
7. TMDLs must include public participation.

* A revised regulation on TMDLs is currently (99-Aug) in draft and has additional requirements.

Figure 1 provides a map of the TMDL segment including important land marks and high volume sampling sites used in the TMDL analysis. The TMDL includes a 79.5 mile segment of the Ohio River from Racine Dam (ORM 237.5) to the West Virginia-Kentucky border (ORM 317). This segment forms a portion of the Ohio-West Virginia state border and ends immediately upstream of the Kentucky border. The RC Byrd Dam splits the TMDL segment at ORM 279.2. The Ohio River Basin drains approximately 40,000 square miles upstream of the TMDL segment.

Major tributaries entering the Ohio River within the segment include the Kanawha and Guyandotte Rivers. The Kanawha River contributes approximately one-quarter of the total flow in the Ohio River at the point of confluence and therefore carries a significant potential to affect Ohio River water quality. The Kanawha River drains approximately 12,000 square miles. The Guyandotte River has lesser flow and corresponding lesser potential to affect the Ohio River and drains an area of approximately 1700 square miles. There are an additional four tributaries within the segment with drainage areas ranging from 150 to 700 square miles (Leading Cr., Raccoon Cr., Symmes Cr., Twelvepole Cr.) and a multitude of smaller tributaries.

## METHODOLOGY

### Water Quality Monitoring Data and Assessment

The Ohio River Valley Water Sanitation Commission collected dioxin samples at sites within the Ohio River TMDL segment, to define boundary conditions (conditions entering the TMDL segments), and at sites upstream of the TMDL segment to define upstream dioxin concentrations. Figure 2 contains a map with locations of all dioxin river sampling locations within the basin. Dioxin samples are collected using a “high volume” method that concentrates 1000 liters (L) of water, effectively lowering the analytical detection level 1000 times. Appendix A contains all sample results for 2,3,7,8-TCDD. Table 1 contains a summary of dioxin monitoring sites and results within or at the boundaries of the TMDL segment for samples collected between June

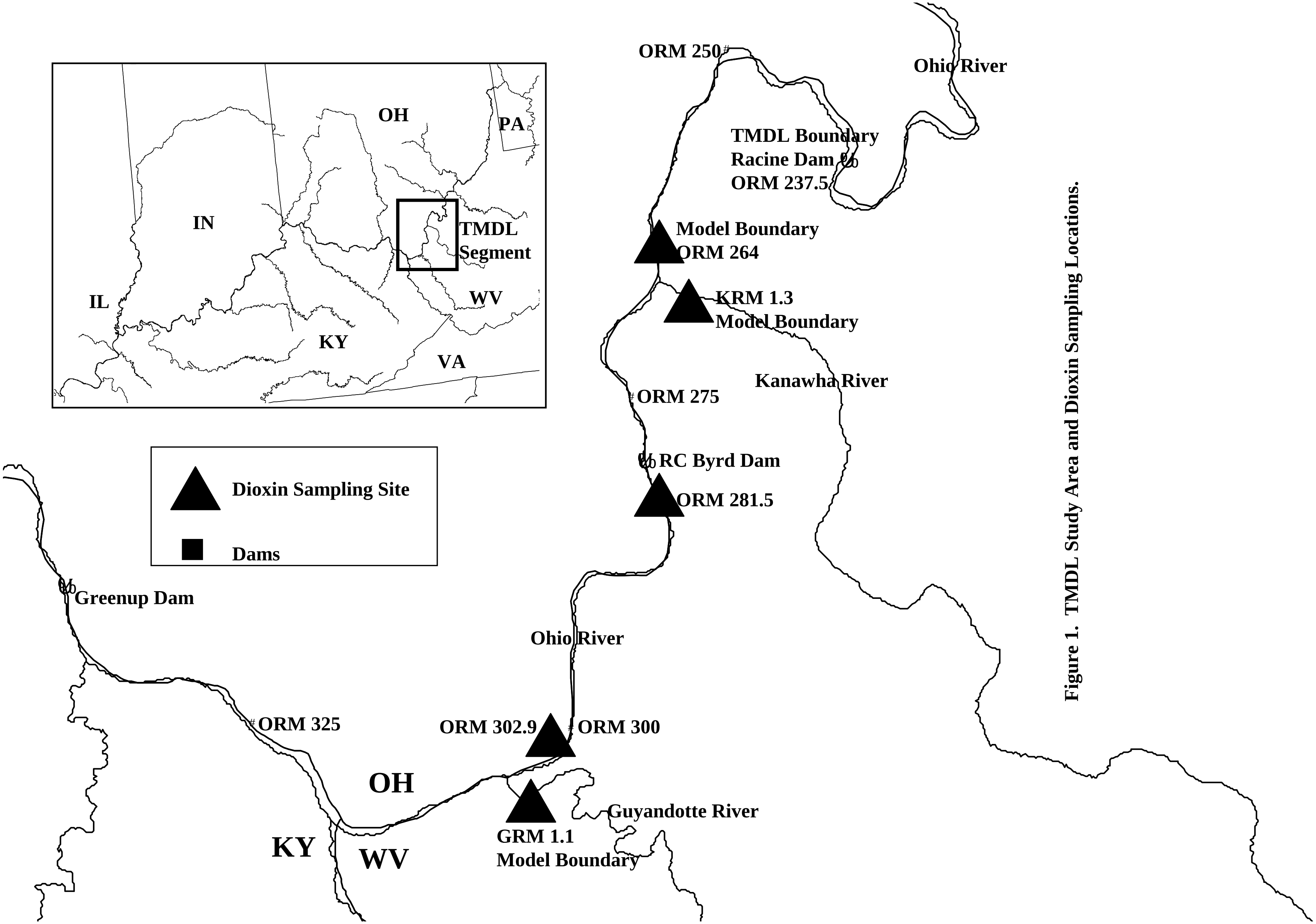

Figure 1.  TMDL Study Area and Dioxin Sampling Locations.

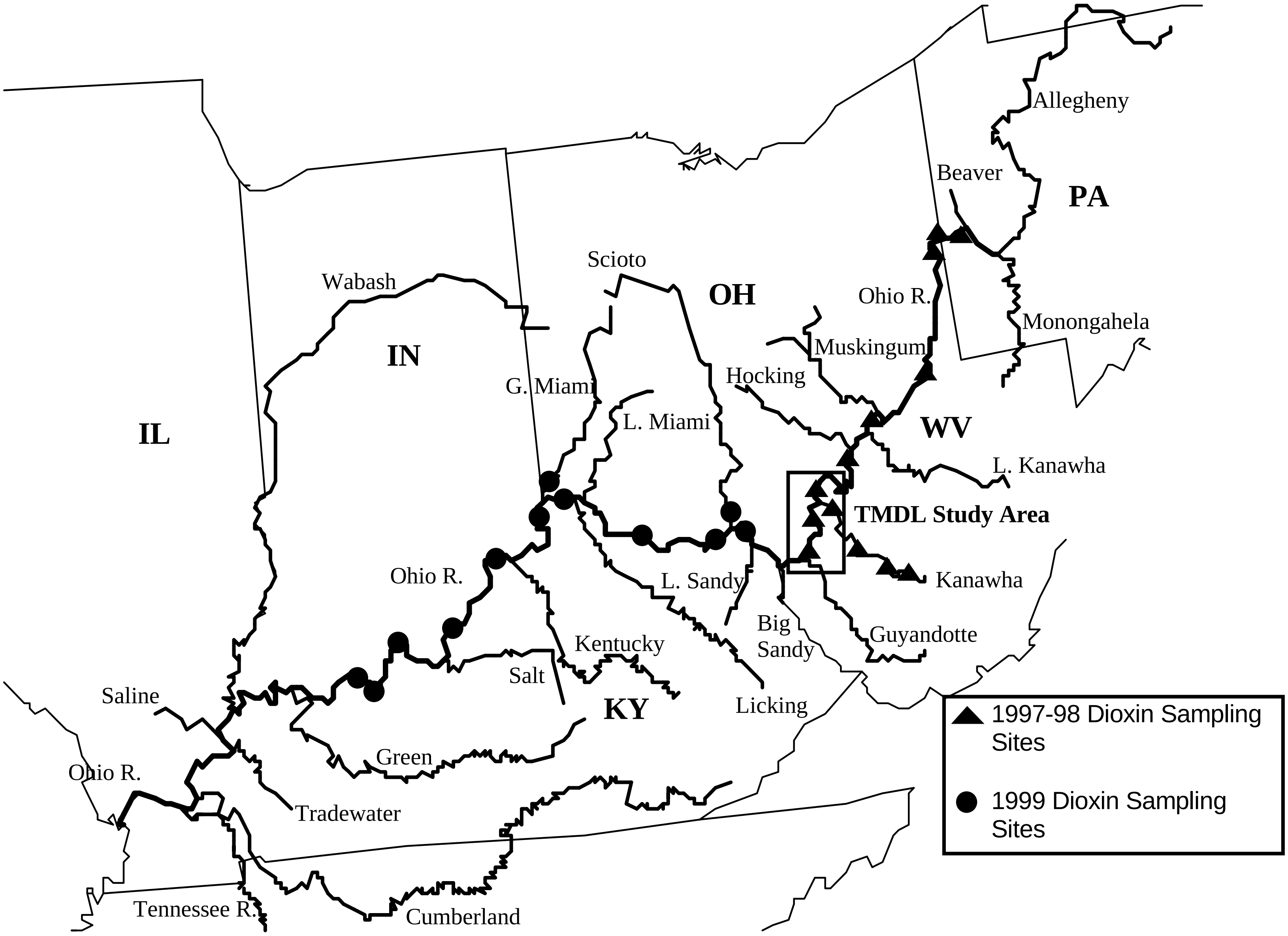

**Figure 2. Dioxin Monitoring Sites within the Ohio River Basin.**

1997 and November 1998 (data collected upstream of the TMDL segment are presented in Figure 10 later in this report).

**Table 1. Summary of Dioxin Data Within the TMDL Segment**

| River/Site | No. Samples | No. Violations | Max. Conc. Total 2,3,7,8-TCDD, pg/L | Min. Conc. Total 2,3,7,8-TCDD, pg/L |
|---|---|---|---|---|
| Ohio RM 264 | 5 | 2 | 0.0710 | 0.0068 |
| Kanawha RM 1.3 | 7 | 7 | 0.4628 | 0.0941 |
| Ohio RM281.5 | 5 | 5 | 0.1364 | 0.0240 |
| Ohio RM 302.9 | 5 | 5 | 0.1671 | 0.0229 |
| Guyandotte RM 1.1 | 2 | 1 | 0.0201 | <0.0010 |

The data indicate frequent water quality standards violations for 2,3,7,8-TCDD in the Ohio River below the confluence with the Kanawha River, which carries a heavy loading of 2,3,7,8-TCDD. Figure 3 presents high volume dioxin sampling results at RC Byrd Dam. The Ohio River above the Kanawha River also violates water quality standards at higher flows.

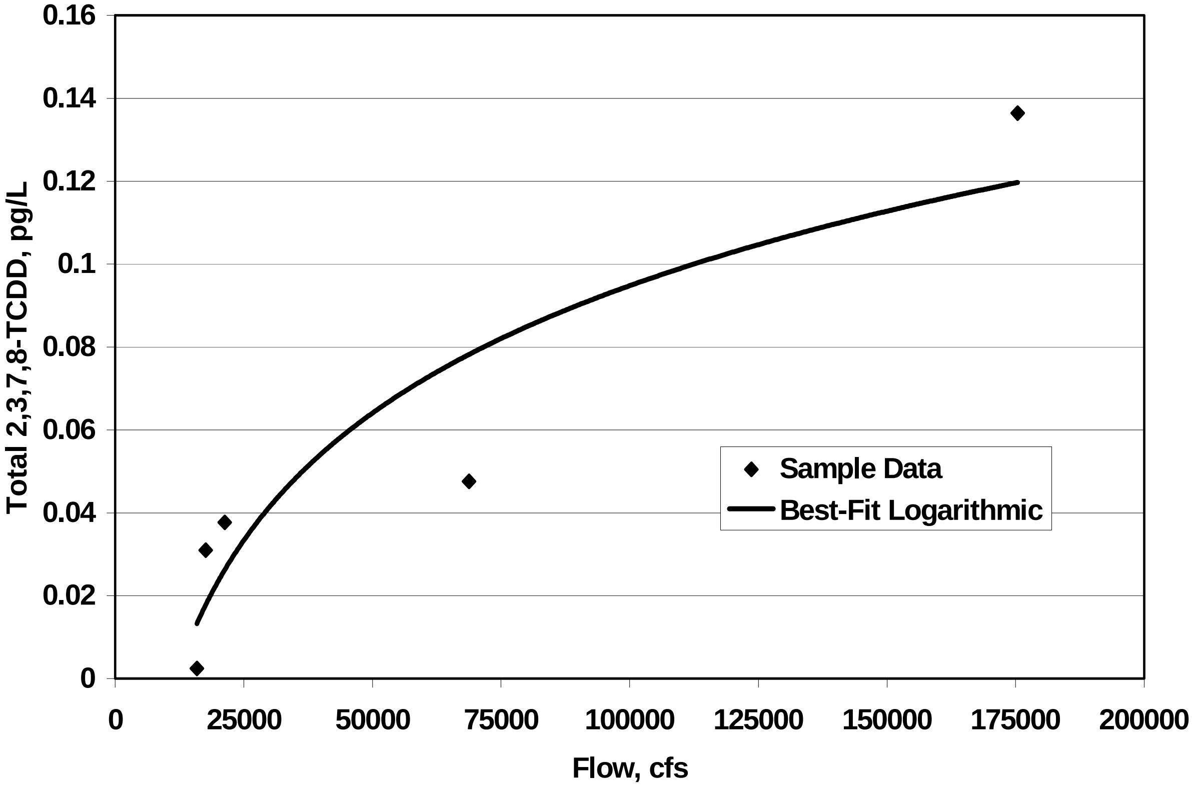

**Figure 3. Total Dioxin Vs. Flow at RC Byrd Dam**

## Water Quality Standards Endpoint

Since the portion of the Ohio River, for which this TMDL is being established, forms the boundary between Ohio and West Virginia, both states' Water Quality Standards for 2,3,7,8-TCDD (dioxin) must be considered in the development of this TMDL. The State of Ohio's Water Quality Standard for the Ohio River is 0.13 pg/L, to be applied at one- tenth the harmonic mean flow, at a cancer risk level (CRL) of $10^{-5}$. Surrounding States WQS also should be considered for consistency. Pennsylvania's Water Quality Standard for dioxin is 0.01 pg/L to be applied at harmonic mean flow, and Kentucky's Water quality standard is 0.013 pg/L at harmonic mean flow.

West Virginia's criteria for dioxin is 0.013 pg/L, however, West Virginia Water Quality Standards Regulations (WV-46-1-8-2.b) defer a final decision on critical flow for carcinogens, in order that the State may further study the issue. Presently, the West Virginia Water Quality Standards Regulations state -- " the regulatory requirement for determining effluent limits for carcinogens shall remain as they were on the date this Rule was proposed." WV 46-1-7.2.b states -- in the absence of any special application, numeric water quality standards shall apply at all times when flow is greater than 7Q10 flow.

In this TMDL application, where only load allocations will be developed, we believe that harmonic mean flow is not inconsistent with West Virginia Water Quality Standards Regulations 46 CSR 1. Because human health criteria assume long-term chronic exposure, harmonic mean flow is the most appropriate flow to describe the critical condition. A coordinated and consistent approach among bordering states has become more important, especially for waters like the Ohio River that are shared.

## Selection of Critical Condition and Seasonality

Concurrently with selection of a numeric endpoint, in this case the Water Quality criteria, TMDLs need to define the environmental condition that will be used when defining allowable loads. TMDLs are usually designed around the concept of "critical condition". The critical condition is defined as the set of environmental conditions, which, if controls are designed to protect, will ensure attainment of standards for all other conditions.

Because 2,3,7,8-TCDD is defined as a carcinogen, harmonic mean flow has been specifically identified as the appropriate flow condition to use with the criterion (EPA Guidance 1991). Dioxin sources on the Ohio River are believed to arise from a mixture of sources. There may be no other single condition that is protective for all other conditions. For this reason, this TMDL does examine an entire range of flow conditions and can define a load allocation that will be protective for different flows. However, for this TMDL harmonic mean flow is the flow condition that will be used for setting allocations.

Seasonality is inherently accounted for in using the harmonic mean flow, since that flow theoretically accounts for conditions over a long period of time.

## Model Selection and Segmentation

After reviewing several models for possible use in performing this TMDL analysis, SMPTOX 4 was selected. This model was selected because it has a sediment component which is critical to the transport of dioxin, because its complexity best matches the available data and current scientific knowledge of dioxin transport and fate mechanisms, and because the model is supported by the US EPA. SMPTOX is a steady-state flow model that simulates transport and fate of chemical pollutants and sediments. The primary purpose of the model is to determine the maximum dioxin loading within the TMDL segment at critical conditions. SMPTOX was determined to be the most appropriate model considering the transport and fate processes to be simulated, the available data for input to the model, and the most appropriate level of complexity. A comprehensive description of the modeling effort is attached in a separate report, Technical Support Document for the Development of an Ohio River Total Maximum Daily Load for 2,3,7,8-TCDD (Dioxin).

The US Army Corps of Engineers' HEC-2 reservoir hydraulic model was used to determine river segmentation and channel geometry for SMPTOX. River flows and downstream water surface elevation are input to HEC-2. Hec-2 then determines cross-sectional profiles from which cross-sectional areas can be calculated for each river segment. The Ohio River was divided into 16 segments within SMPTOX varying in length from less than one mile to over seven miles. These segments were determined based on changes longitudinally in river cross-sectional area and velocity determined with HEC-2.

## Determination of Boundary Conditions

Model boundaries include the Ohio River at ORM 264 (upstream of the Kanawha River), the Kanawha River, and the Guyandotte River. The upstream model boundary at ORM 264 differs from the upstream boundary of the TMDL segment at ORM 237.5. The model boundary at ORM 264 coincides with a high volume dioxin sampling location and is assumed to be representative of the upstream TMDL segment boundary. This difference between the locations of the modeling and TMDL boundaries occurred in part because the TMDL segment was extended from ORM 264 to ORM 237.5 after the modeling effort was initiated. It was decided that there was no reason to extend the model upstream to the upper boundary of the TMDL segment since it is believed that ORM 264 would be representative of conditions at ORM 237.5, since there are known or suspected dioxin sources between the two locations.

Boundary inputs to be determined include flow, sediment concentrations, and dioxin concentrations. Sediment and dioxin concentrations at input boundaries to the TMDL segment are estimated using high volume survey results. Dioxin and sediment concentrations are known for several flow conditions and are estimated at other flow conditions (including high flow conditions) using a best-fit model. Figure 4 provides particulate dioxin concentrations versus flow along with the best-fit model for the Kanawha River boundary. The same is shown in Figure 5 for the Ohio River upstream TMDL segment boundary at ORM 264. At critical conditions, the *particulate* dioxin concentration is determined from the best-fit model, and the *average dissolved* dioxin concentration is added to it to calculate total dioxin at the boundaries. More detail on this procedure can be found in the modeling report.

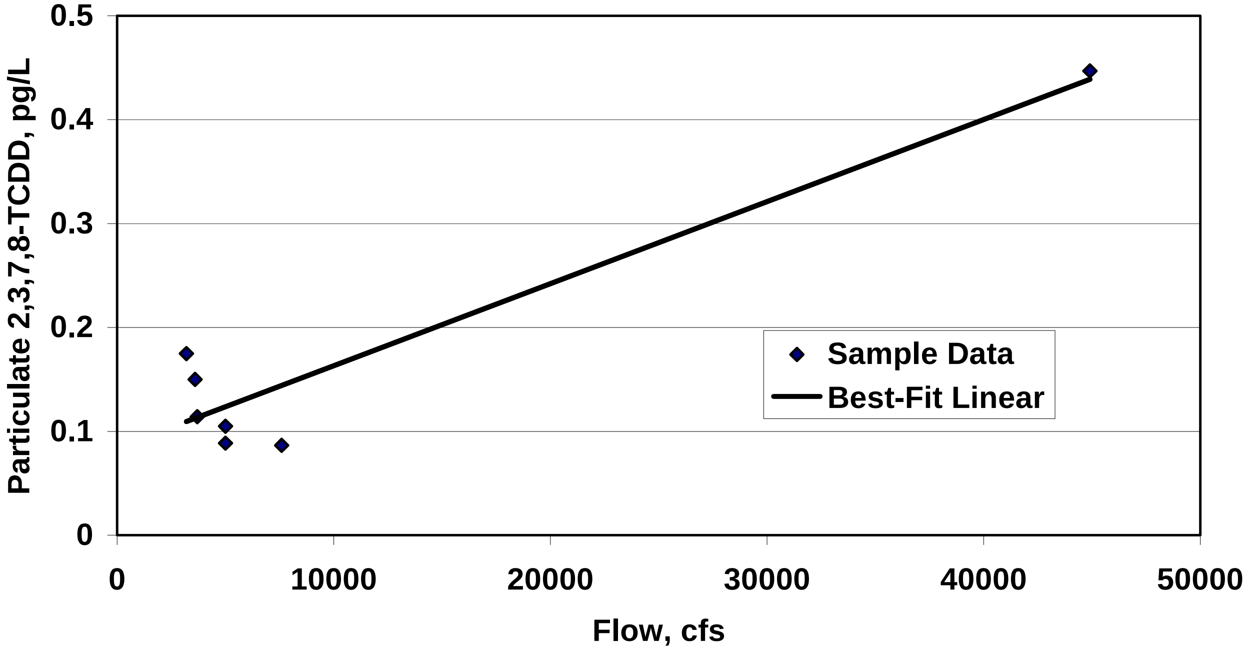

Figure 4. Kanawha River Boundary – Particulate Dioxin Vs. Flow

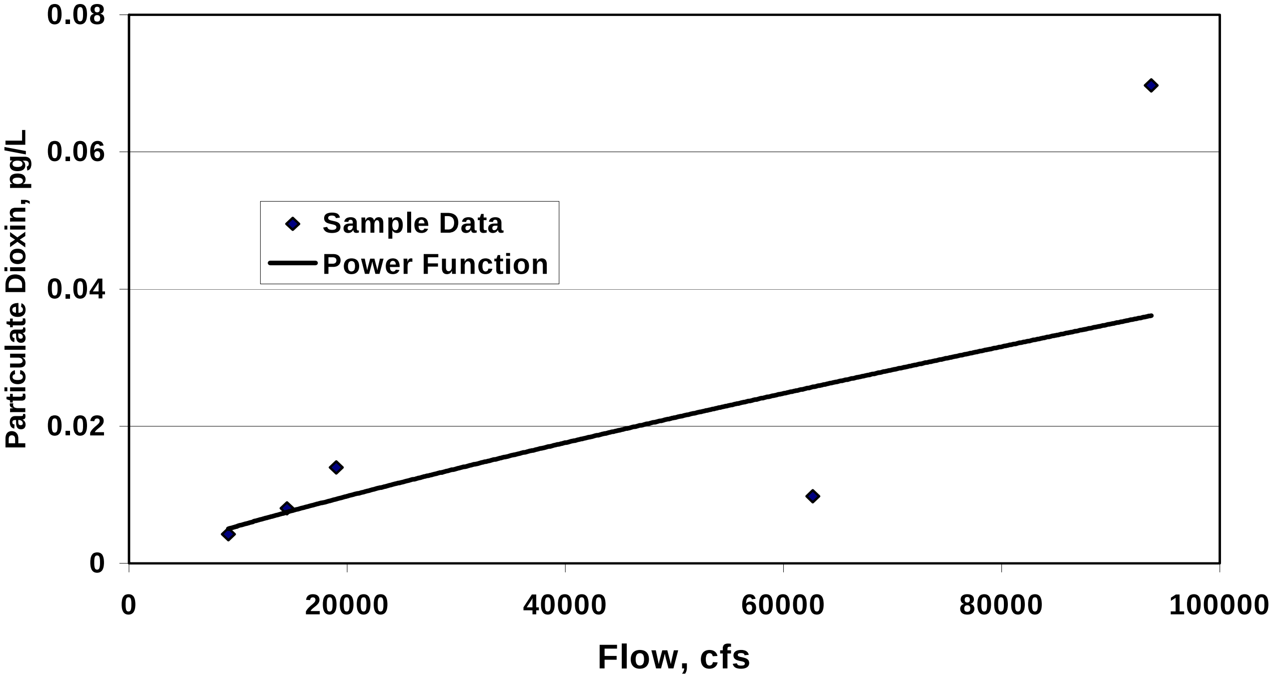

Figure 5. Ohio River TMDL Upstream Boundary – Particulate Dioxin Vs. Flow.

### Estimation of Model Variables

In addition to boundary inputs, a number of other model variables were developed as described in detail in the Technical Support Document. The more important variables in terms of model sensitivity to changes in input variable values include: sediment settling and resuspension velocities, and partition coefficient (in addition to dioxin boundary loads). These variables were developed with the aid of field measurements. Longitudinal suspended solids surveys were conducted for the express purpose of developing settling and resuspension velocities. High volume sampling generates dissolved and particulate concentrations of dioxin which are in tern used to calculate a partition coefficient. Other model input variables include hydrolysis, biodegradation, bed depth, dispersion, bed $f_{oc}$, bed porosity and density, mixing factor, and photolysis. These variables are quite technical in nature, thus the Technical Support Document should be referenced for a complete explanation of these parameters.

## RESULTS

### Total Maximum Daily Load Analysis

In order to illustrate the variation in dioxin at different flow conditions, the model was executed at three flows: seven-day/ten-year low flow, harmonic mean flow, and at the one-year flood. These flows represent low, moderate, and high flow conditions respectively, with the harmonic mean flow being specified as the critical condition, or the condition under which allocations would be applied. Dioxin concentrations based on model results are presented graphically in Figure 6.

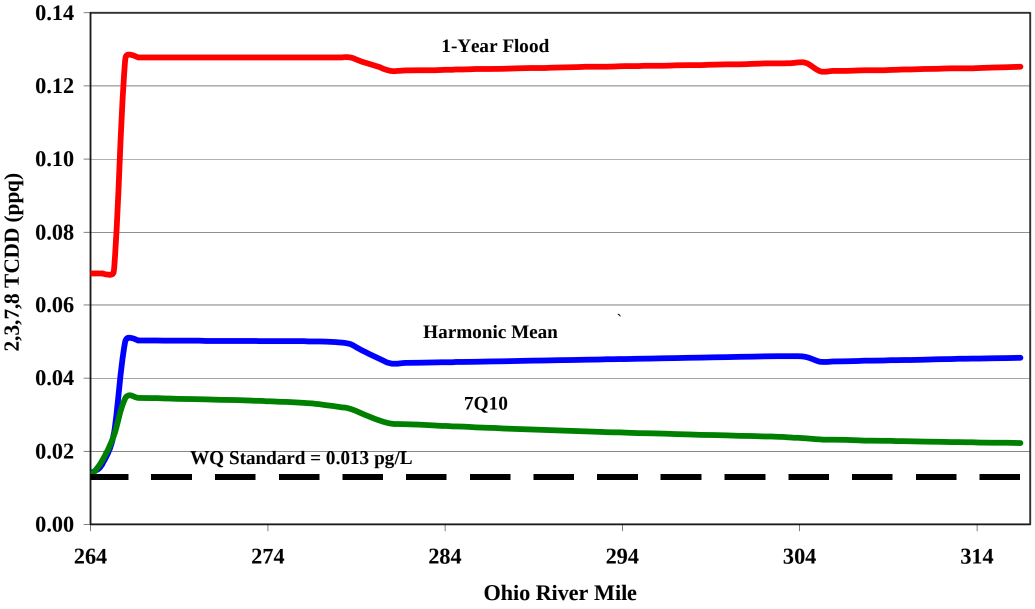

**Figure 6. SMPTOX4 Model Results at Various Flows.**

ORM 266 (critical river location) is the location on the Ohio River with the highest dioxin concentrations and loads, at all flow conditions modeled, and is positioned immediately downstream of the confluence with the Kanawha River. The water quality standard of 0.013 pg/L is violated at all three flows, at this critical river location, but are highest during the high flow, one-year flood. The maximum modeled concentration of total 2,3,7,8-TCDD is 0.128 pg/L (parts per quadrillion), which occurred immediately downstream of the Kanawha River at ORM 266, the critical location.

Figure 7 plots modeled dioxin loads at low, moderate and high flows at ORM 266. A best-fit power function trend line having an r-squared value of 0.9988 can be used to estimate Ohio River dioxin loads at flows other than those modeled. The equation for the best-fit power function trend line is $y=0.0023x^{1.3917}$ (y in pg/L; x in cfs) which can be used to calculate a predicted dioxin load for any flow. The total 2,3,7,8-TCDD load (modeled) at the critical location in the Ohio River (ORM 266), at the critical harmonic mean flow, is 4245 ug/day. The dioxin total maximum daily load, or the highest load that would not result in violation of the 0.013 pg/L water quality standard at the harmonic mean flow (listed as capacity in Table 2), is 1097 ug/day. Therefore, a 74 percent reduction would be needed to meet water quality standards at the critical harmonic mean flow condition. The Ohio River upstream of the Kanawha River accounts for approximately nineteen percent of the total dioxin load at the harmonic mean flow, while the Kanawha River accounts for the remaining 81 percent of the Ohio River dioxin load. Even though the Ohio River meets water quality standards at the harmonic mean flow, a proportionate reduction (19 percent or 152 ug/day) in its dioxin load will be required to assist in meeting the water quality standard downstream. The remaining reduction need to meet water quality standards, 3452 ug/day or 87 percent of the Kanawha’s dioxin load at harmonic mean flow, will be obtained from sources within the Kanawha River Basin.

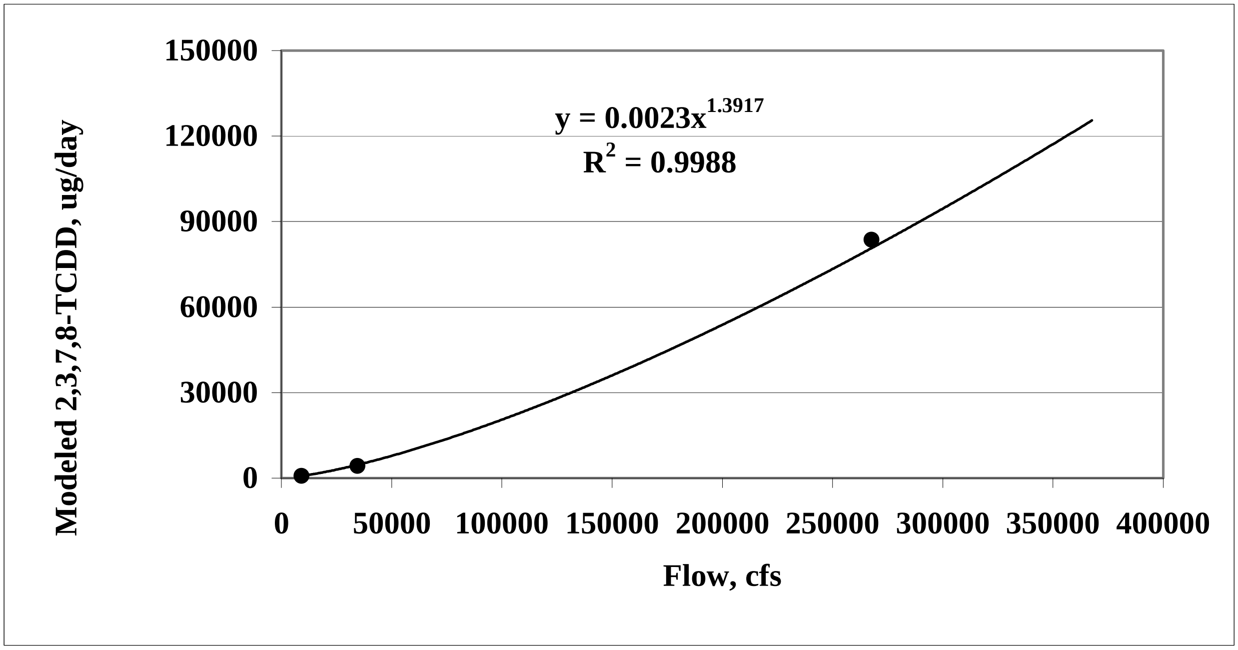

**Figure 7. Dioxin Loads at Low, Moderate, and High Flows in the Ohio River at ORM 266**

At the one-year flood flow condition, the maximum modeled total dioxin load in the Ohio River is 83,693 ug/day, while the river capacity at that flow is 8,513 ug/day. Therefore, at the one-year flood high flow condition, a 90 percent reduction of the total dioxin load would be necessary not to exceed the water quality criterion. At the high flow, the Ohio River upstream of the Kanawha River accounts for approximately 45 percent of the total Ohio River dioxin load, while the Kanawha River accounts for the remaining 55 percent. The Guyandotte River does not have a measurable affect on dioxin levels in the Ohio River. In fact, based on modeling results, Ohio River dioxin concentrations downstream of the Guyandotte River decrease since the dilution from the Guyandotte River has a greater affect than its dioxin loading. Table 2 provides the percent load reductions for dioxin necessary to meet water quality standards at the seven-day, ten-year low flow, harmonic mean flow, and one-year flood high flow at various locations. Figure 8 shows percent load reductions necessary to meet water quality standards for the Ohio River at the upstream boundary of the TMDL segment and at the worst-case location on the Ohio River immediately downstream of the Kanawha River.

**Table 2. 2,3,7,8-TCDD Reductions Necessary to Meet Ohio River Dioxin WQSs.**

| | Flow, cfs | Conc., pg/L | Capacity ug/day | Loading ug/day | Reduction to meet WQS |
|---|---:|---:|---:|---:|---:|
| **7Q10 Low Flow** | | | | | |
| Ohio R.Upstream of Kanawha R. | 6700 | 0.0052 | 213 | 85 | 16 ug/d (19 %) |
| Kanawha R. | 2420 | 0.1173 | 77 | 694 | 468 ug/d (67 %) |
| Ohio R. Downstream Of Kanawha R., ORM 266 | 9120 | 0.0347 | 290 | 774 | 484 ug/d (63%) |
| Guyandotte R. | 180 | 0.0005 | 6 | 0 | N/A |
| **Harmonic Mean Flow** | | | | | |
| Ohio R.Upstream of Kanawha R. | 26000 | 0.0126 | 827 | 801 | 152 ug/d (19 %) |
| Kanawha R. | 8500 | 0.1660 | 270 | 3452 | 2996 ug/d (87 %) |
| Ohio R. Downstream Of Kanawha R., ORM 266 | 34500 | 0.0503 | 1097 | 4245 | 3148 ug/d (74 %) |
| Guyandotte R. | 1400 | 0.0011 | 45 | 4 | N/A |
| **One-Year Flood** | | | | | |
| Ohio R.Upstream of Kanawha R. | 225000 | 0.0687 | 7155 | 37809 | 33826 ug/d (89 %) |
| Kanawha R. | 42700 | 0.4396 | 1358 | 45914 | 41344 ug/d (90 %) |
| Ohio R. Downstream Of Kanawha R., ORM 266 | 267700 | 0.1278 | 8513 | 83683 | 75170 ug/d (90 %) |
| Guyandotte R. | 6000 | 0.0159 | 191 | 233 | N/A |

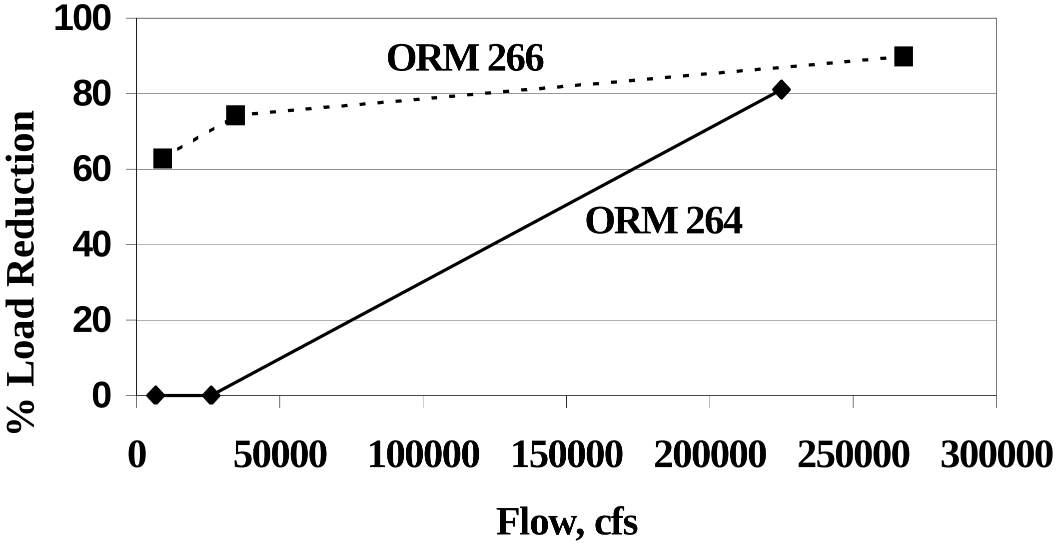

**Figure 8. Ohio River Dioxin Load Reductions Necessary to Meet Water Quality Standards at Various Flows.**

## Margin of Safety

The applicable ambient water quality criterion for 2,3,7,8-TCDD is 0.013 pg/L which is based on a $10^{-6}$ cancer risk level. This criterion is designed to protect human health from long-term (lifetime) exposure. The harmonic mean flow is theoretically representative of an average flow over a lifetime. The recommended use of the long-term harmonic mean flow for carcinogens has been derived from the definition of the human health criteria (HHC) for carcinogenic pollutants. The adverse impacts of carcinogenic pollutants is estimated in terms of life-time intake. Therefore, estimation of the load reduction necessary to achieve water quality standards for dioxin at the harmonic mean flow will be protective of human health and provide an intrinsic margin of safety. The estimated Ohio River reduction in loading of 2,3,7,8-TCDD, at 7Q10 flow, at the critical point downstream from the Kanawha River, based on the model is 63 percent. The estimated load reduction using the harmonic mean flow at the same location is 74 percent. Therefore, load allocations designed to meet this critical condition of harmonic mean flow would provide an increased margin of safety over 7Q10 for the protection of human health over a lifetime exposure.

## Source Assessment

Very little is known about specific source contributions of dioxin to the Ohio River TMDL segment. Potential sources can be categorized as follows:

- Sources within the Ohio River TMDL segment.
- Sources upstream of the TMDL segment.
- Point sources.
- Nonpoint sources.
- Surface runoff carrying contaminated sediment.
- Resuspension of contaminated bed sediments.

- Atmospheric deposition.
- Groundwater infiltration.
- Diffusion from bed sediment pore water

## Kanawha River Total Maximum Daily Load

Certain sources in the Kanawha River Basin have been identified and are described in a June 2000 report, Dioxin TMDL Development for Kanawha River, Pocatalico River, and Armour Creek, West Virginia (Limno-Tech, Inc., Ann Arbor. MI). Allocations to Kanawha Basin sources will be addressed under the Kanawha River Dioxin TMDL. The Ohio River TMDL analysis simply treats the Kanawha River as a combined dioxin load to the Ohio River. Allocations to Kanawha River sources necessary to meet water quality standards must be designed to meet Ohio River water quality standards as well. The Ohio River Valley Water Sanitation Compact requires that tributaries be of equal or better quality than the Ohio River.

## Inventory of Potential and Confirmed Dioxin Sources in the Ohio River Basin

Again, little is known about specific sources of dioxin to Ohio River Basin surface waters. Most of the known contaminated sites occur in the Kanawha Basin although dioxin loads from these sites, if any, have not been determined. In a 1997 Commission report, Dioxin in the Ohio River Basin, an in-depth review of known and potential dioxin sources in the Ohio Basin was conducted. Figure 9 and Appendix B provide results of this search. Thirty-five **potential** sources, in the Ohio Basin and upstream of the Kanawha Basin, were identified. They include industries known to generate dioxin, such as cement kilns known to produce atmospheric emissions, contaminated soil sites which may or may not be contributing dioxin to surface water through erosion and runoff, etc. Of the thirty-five potential sources, seven were deemed to be "higher probability" of contributing dioxin to surface water. In addition to the listed sources, an additional Superfund site contaminated with, among other pollutants, dioxin has been discovered at ORM 10, on Neville Island in the Pittsburgh area.

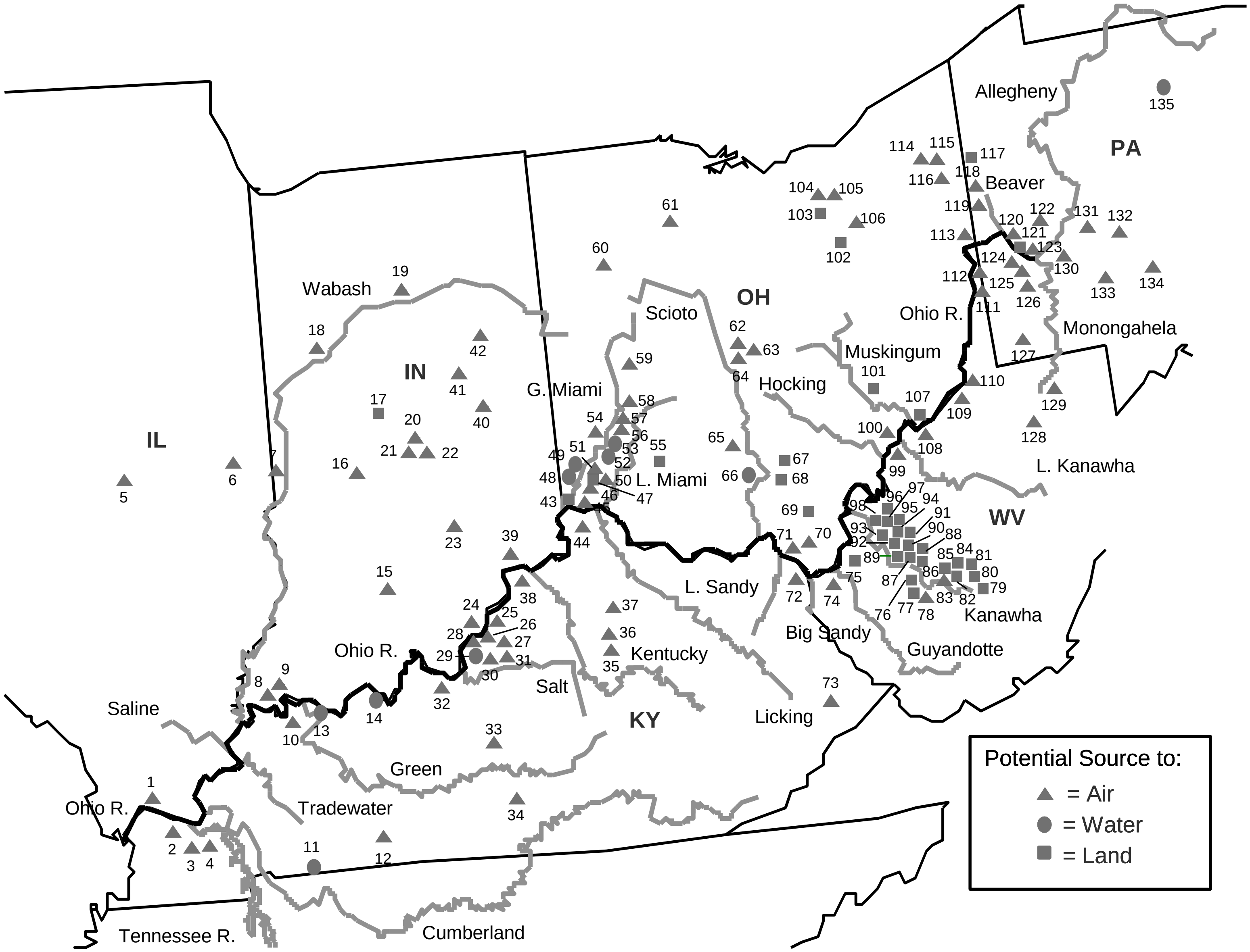

Figure 9. Potential Dioxin Sources to Surface Waters in the Ohio River Basin.

### Upper-Ohio River Sources

Figure 10 displays high volume dioxin sampling results from upper Ohio River surveys conducted in 1998. Dioxin concentrations are highest at ORM 20.2 (downstream of Pittsburgh) and gradually decrease in a downstream direction (with the exception of the sampling location at ORM 175.1). This might indicate a significant source(s) above the most upstream high volume sampling site, possibly in the Pittsburgh area or further upstream on the Monongahela or Allegeheny Rivers. At ORM20.2, dioxin concentrations are generally highest and decrease in a downstream direction with increasing flow which suggests the possibility of point source contributions. A 2,3,7,8-TCDD concentration of 0.0244 pg/L was measured at ORM 20.2 at a low flow of 7,700 cfs. This concentration is almost twice the water quality criterion of 0.013 pg/L. Sources upstream of ORM 20 should be investigated.

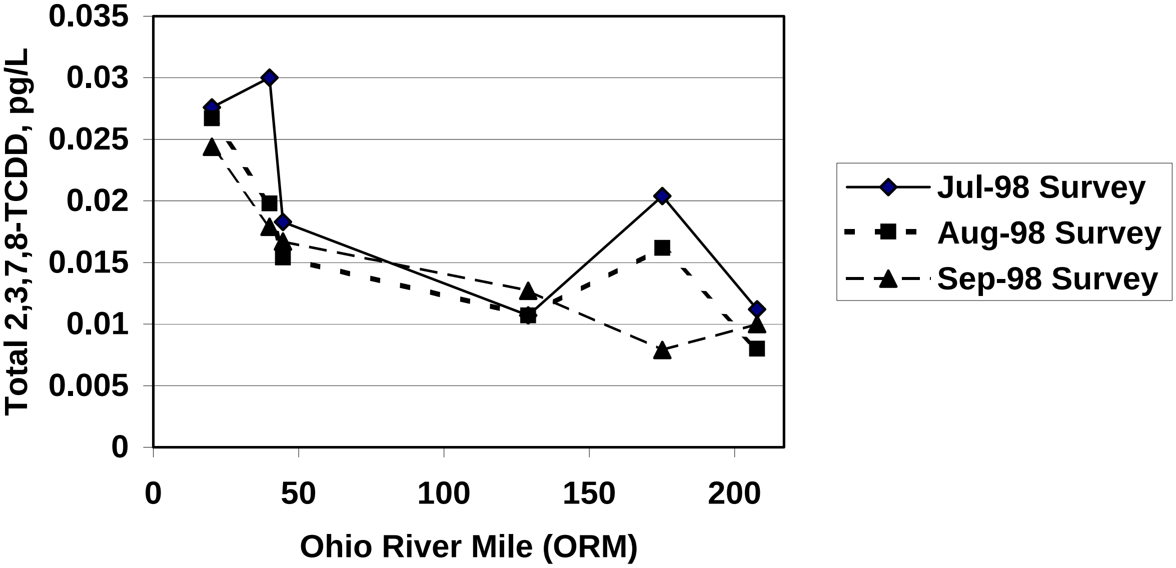

Figure 10. Upper-Ohio River Dioxin Sample Data from 1998.

In addition, there is an increase in dioxin concentration at ORM 175.1, possibly the result of a known contaminated site, or from sources on the Muskingum River. On average, the increase is 0.0035 pg/L or approximately 25 percent of the stream criterion. This increase, as an exception to an otherwise decreasing trend in a downstream direction, should be investigated further to identify sources.

### Source Loadings by Category

There is no net increase of dioxin within the TMDL segment itself (with the exception of the Kanawha River load) as model results demonstrate in Figure 6. Additionally, atmospheric deposition of 2,3,7,8-TCDD has been determined, based on a limited amount of sampling data, to be insignificant. Therefore, all important sources of dioxin that need to be accounted for are upstream of the TMDL segment, either in the Ohio River Basin upstream of ORM 264 or in the Kanawha Basin. Modeling results indicate that diffusion from pore water (water trapped in the pore spaces in the river bed) has been determined to be negligible. Low flow loads might typically be attributed to dry weather sources such as point sources and contributions from contaminated groundwater. Conversely, high flow loads might typically be attributed to wet weather sources such as resuspended bed sediments and contaminated runoff. High flow related sources are much greater than from low flow sources.

**Summary of Findings**

1) Development of a total maximum daily load for the Ohio River from river mile 237.5 to 317.0 must be completed by September 2000 as required by a Federal Consent Order.

2) The Ohio River does not meet the water quality standard of 0.013 pg/L for dioxin downstream of the confluence with the Kanawha River even under the most favorable conditions. The water quality standard is designed to protect human health from long-term exposure from ingestion of contaminated water and fish.

3) The harmonic mean flow was selected as the appropriate critical flow condition as it best represents conditions occurring over life-time exposures to carcinogens.

4) Based on modeling results at the harmonic mean flow, the maximum total 2,3,7,8-TCDD load in the Ohio River is 4245 ug/day. This occurs immediately downstream of the Kanawha River. A 74 percent reduction in the Ohio River 2,3,7,8-TCDD load would be necessary to meet the water quality standard at the critical condition. Of the total 2,3,7,8-TCDD loading at harmonic mean flow, 81 percent originates from the Kanawha River Basin while the remainder originates from the upper Ohio River Basin.

5) Proportionate reductions in dioxin loads, necessary to meet the water quality standard in the Ohio River at ORM 266 (immediately downstream of confluence with Kanawha River) will be required from the Kanawha River as well as the upper Ohio River. The Ohio River marginally meets water quality standards at the critical harmonic mean flow. Even so, because the upper Ohio River contributes 19 percent of the total dioxin load that exceeds standards downstream, that proportionate reduction (152 ug/day) will be required from the upper Ohio River. The remaining reduction necessary to meet the water quality standard will be obtained from the Kanawha River, which equals 2996 ug/day or 87 percent of the Kanawha’s total dioxin loading at critical conditions.

6) An inherent margin of safety is provided by selecting the harmonic mean flow as the critical condition over the 7Q10 low flow. At the harmonic mean flow, the reduction necessary to achieve water quality standards is 74 percent, while only 63 percent at the 7Q10 low flow.

7) Dioxin concentrations and loads increase with increasing flow and increasing suspended solids loads.

8) The largest dioxin loads for the Ohio River occur at high flows, immediately downstream of the confluence with the Kanawha River at ORM 266.

9) The highest flow condition simulated by the model is a one-year flood. The Ohio River flow corresponding to a one-year flood, immediately downstream of the confluence with the Kanawha River, is 267,700 cfs. This is the highest flow at which it is believed monitoring data can be used to validate modeling results.

10) At the one-year flood, the Ohio River daily load of 2,3,7,8-TCDD is 83,726 ug/day immediately downstream of the Kanawha River. The loading capacity necessary not to exceed the stream criterion at this flow is 8,491 ug/day, an order of magnitude less. The total daily load of 2,3,7,8-TCDD would need to be reduced 90 percent in order to meet water quality standards. At this flow, the Kanawha river contributes 55 percent of the total Ohio River dioxin loading while the upper Ohio River Basin contributes the remainder.

11) There is not net increase of dioxin within the TMDL segment except from that of the Kanawha River. The total daily loading of dioxin results from sources upstream of the TMDL segment.

12) Monitoring results indicate that atmospheric contributions of 2,3,7,8-TCDD are negligible.

13) Very little is known about specific sources of dioxin in the Ohio River Basin.

14) An upper-river dioxin survey indicates the potential presence of a significant point source(s) of 2,3,7,8-TCDD in the Ohio River upstream of ORM 20 (Pittsburgh area), and also between ORM 129 and ORM 207 (Marietta/Parkersburg area).

15) A Kanawha River TMDL identifies a number of sources in the Kanawha Basin.

16) There are significant differences in the application of states water quality standards for carcinogens for the Ohio River.

## Future Areas of Study

1) Potential dioxin sources in the Ohio Basin upstream of ORM 20, and between ORM 129 and 175, should be investigated further. Loads from such sources should be quantified if possible.

2) Dioxin loads from sources identified in the Kanawha River Basin should be quantified and reduced if possible.

3) Studies are needed to determine the nature and extent of resuspension of contaminated sediments in the upper Ohio River.

4) Consistency in the application of water quality standards for dioxin (and other carcinogens having human health-based criteria ) for the Ohio River needs to be achieved.

5) It is evident that additional dioxin congeners are typically present, each of which has a toxicity equivalence factor that allows for its expression in terms of the 2,3,7,8-TCDD congener.

## DISCUSSION

### Follow Up Monitoring Plan

The purpose of the follow up monitoring plan is to identify and quantify if possible specific sources of dioxin contributing to the upstream load entering the TMDL segment from the upper-Ohio River Basin. While there are suspected sources contributing dioxin to the TMDL segment from the Kanawha River Basin, this monitoring plan only addresses Ohio River sources. A Kanawha River TMDL will address sources contributing dioxin to the Ohio River.

No specific sources of 2,3,7,8-TCDD have been identified to date in the upper Ohio river Basin, even though a number of sources are suspected. Funding for this monitoring has been provided through US EPA Region 3 as a grant to the Ohio River Watershed Pollutant Reduction Program. The monitoring effort will begin in 2000 and be completed by 2001. It is anticipated that an additional follow up monitoring plan may be necessary for 2001-2002 in order to complete a thorough investigation of dioxin sources in the upper Ohio River.

Design of the following monitoring plan is based on previous dioxin monitoring and modeling efforts and presented within this report previously. Specifically, Figure 10 identifies specific locations in the upper Ohio River that should be investigated further, areas targeted by this follow up monitoring plan. In addition, modeling results suggest resuspension of contaminated sediments as a potential major source in the upper Ohio River, so this monitoring plan addresses this source also.

### Monitoring to Identify Dioxin Sources in the Upper Ohio River Basin

An Upper-Ohio River longitudinal survey of dioxin, utilizing the high-volume sampling technique, was conducted in 1998. Results of that survey suggest potential sources in the Pittsburgh area between Ohio River Miles (ORM) 0 and 129, and the Marietta, OH area between ORM 129 and 175. However, no specific sources of dioxin to the Ohio River in these areas are known/quantified, even though dioxin-contaminated sites (having potential impacts) have been identified. In addition, there are a number of potential sources identified in a 1995 study conducted by ORSANCO (Figure 9). The focus of this objective is on narrowing the field of potential dioxin sources. Figure 11 is a map of high volume dioxin sampling locations discussed below which are to be included in the follow up monitoring plan.

### Task 1 - Pittsburgh-Area Dioxin Source Investigation Est. Cost: $ 123,000

This task involves narrowing the field of dioxin sources in the Pittsburgh area (ORM 0 to 129). There is one known dioxin-contaminated site along the Ohio River on Neville Island (ORM 10). In addition, there is a high density of direct discharges along the upper-Ohio River. Sampling locations are listed below and shown on Figure 11. Two rounds of high-volume sampling (at higher and lower flows) for dioxin will be completed including measurements of flow, total suspended solids (TSS), and TOC.

| High-Volume Sampling Sites | Rationale |
|---|---|
| Allegheny River (near mouth) | Upstream boundary |
| Monongahela River (near mouth) | Upstream boundary |
| 1. ORM 4 | Upstream of contaminated site |
| 2. ORM 10 | Downstream of contaminated site |
| 3. ORM 20 | Repeat site from 1998 survey |
| 4. Beaver River | Major trib w/potential sources |
| 5. ORM30 | Cover gaps |
| 6. ORM 40 | Repeat site from 1998 survey |
| 7. ORM 70 | Cover gaps |
| 8. ORM100 | Cover gaps |
| 9. ORM 129 | Repeat site from 1998 survey/downstream boundary |

### Task 2 - Marietta-Area Dioxin Source Investigation Est. Cost: $ 94,000

This task involves narrowing the field of dioxin sources in the Marietta area (ORM 129 to 207). There is one known dioxin-contaminated site at ORM 173 (at confluence with Muskingum River). Sampling locations are listed below and shown on Figure 11. Two rounds of high-volume sampling (at higher and lower flows) for dioxin will be completed including measurements of flow, total suspended solids (TSS), and TOC.

| High-Volume Sampling Sites | Rationale |
|---|---|
| 9. ORM 129 | Repeat site from 1998 survey/upstream boundary |
| 10. ORM 150 | Upstream Marietta urban area |
| 11. ORM 171 | Upstream contaminated site, downstream Marietta |
| 12. Muskingum River | Potential sources exist in Muskingum basin |
| 13. ORM 175 | Repeat site from 1998; downstream contaminated site |
| 14. ORM 185 | Further downstream of contaminated site |
| 15. ORM 207 | Repeat site from 1998 survey |
| 16. ORM 264 | Upstream TMDL boundary |

### Task 3 - Upper Ohio River Bottom Sediment Longitudinal Survey; Est. Cost $ 79,000

This survey will characterize Ohio River bottom sediments from Pittsburgh through the TMDL segment (ORM 0 to ORM 317). It is suspected that much of the dioxin load results from resuspension of existing contaminated sediments. The data will be used to help determine whether this assumption is correct as well as to identify hot spots. One bottom sediment sample will be collected and analyzed for dioxin every five miles from ORM 0 to ORM 317.

**Task 4 - Atmospheric Dioxin Sampling Est. Cost $ 37,000**

Two stations in the Pittsburgh area and two stations in the Marietta area will be sampled four times (quarterly) for dioxin to determine atmospheric contributions to water.

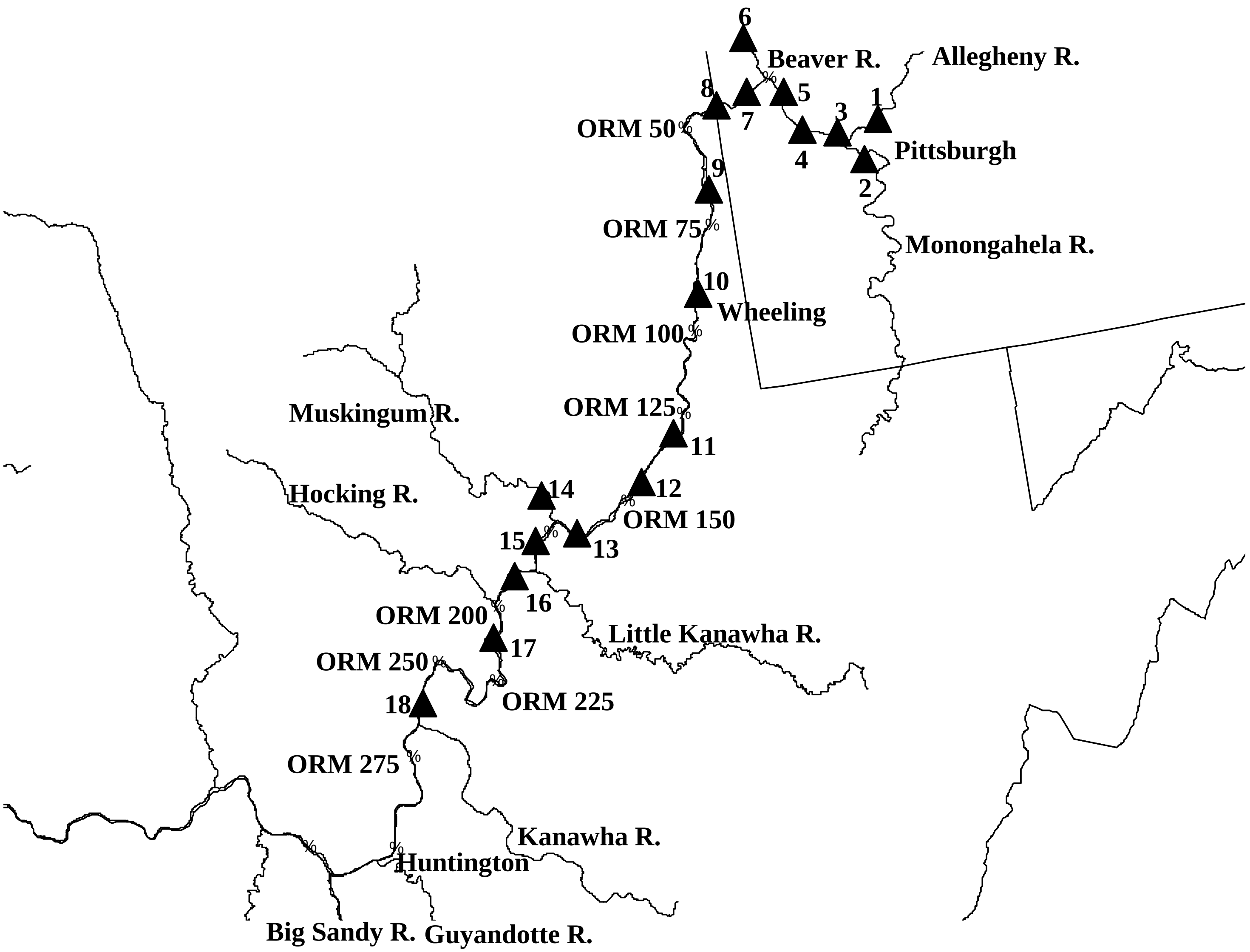

Figure 11. Dioxin Source Investigation Survey Sites.

# APPENDIX A:  ORSANCO High Volume Water Sampling Results

## Ohio River Mile 20.2

| Date sampled | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/7/98 | 19500 | 0.0037 | 0.0239 | 0.0276 | 0.0148 | 0.2190 | 0.2338 |
| 8/4/98 | 5,000 | <0.00156 | 0.0259 | 0.0267 | 0.0000 | 0.0000 | 0.0000 |
| 9/15/98 | 7,700 | <0.00092 | 0.0239 | 0.0244 | 0.0126 | 0.1580 | 0.1706 |
| Avg. | | | | 0.0262 | | | 0.1348 |

## Ohio River Mile 40.0

| Date sampled | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/8/98 | 14700 | 0.0020 | 0.0280 | 0.0300 | 0.0185 | 0.2460 | 0.2645 |
| 8/5/98 | 7300 | <0.00097 | 0.0193 | 0.0198 | 0.0000 | 0.0000 | 0.0000 |
| 9/16/98 | 7800 | <0.00092 | 0.0174 | 0.0179 | 0.0158 | 0.1310 | 0.1310 |
| Avg. | | | | 0.0226 | | | 0.1318 |

## Ohio River Mile 44.6

| Date sampled | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/9/98 | 21700 | 0.0032 | 0.0151 | 0.0183 | 0.0174 | 0.1790 | 0.1964 |
| 8/6/98 | 7,800 | <0.00049 | 0.0152 | 0.0154 | 0.0000 | 0.0000 | 0.0000 |
| 9/17/98 | 7,100 | <0.00072 | 0.0163 | 0.0167 | 0.0160 | 0.1170 | 0.1330 |
| Avg. | | | | 0.0168 | | | 0.1098 |

## Ohio River Mile 129.0

| Date sampled | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/14/98 | 17000 | 0.0025 | 0.0083 | 0.0107 | 0.0203 | 0.1070 | 0.1273 |
| 8/11/98 | 10,500 | <0.00059 | 0.0104 | 0.0107 | 0.0264 | 0.1100 | 0.1364 |
| 9/22/98 | 10,100 | 0.0009 | 0.0118 | 0.0127 | 0.0085 | 0.1110 | 0.1195 |
| Avg. | | | | 0.0114 | | | 0.1277 |

## Ohio River Mile 175.1

| Date sampled | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/15/98 | 34600 | 0.0010 | 0.0194 | 0.0204 | 0.0088 | 0.2830 | 0.2918 |
| 8/12/98 | 19,100 | <0.00149 | 0.0155 | 0.0162 | 0.0000 | 0.1580 | 0.1580 |
| 9/23/98 | 14,200 | <0.00025 | 0.0078 | 0.0079 | 0.0075 | 0.1000 | 0.1075 |
| Avg. | | | | 0.0149 | | | 0.1858 |

## Ohio River Mile 207.7

| Date sampled | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|
| | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/16/98 | 32500 | 0.0017 | 0.0095 | 0.0112 | 0.0198 | 0.2340 | 0.2538 |
| 8/13/98 | 20,500 | <0.00032 | 0.0078 | 0.0080 | 0.0223 | 0.2200 | 0.2423 |
| 9/24/98 | 12,000 | 0.0035 | 0.0065 | 0.0100 | 0.0207 | 0.1310 | 0.1517 |
| Avg. | | | | 0.0097 | | | 0.2159 |

### Kanawha River Mile 1.3

| Date sampled | Flowsed Flow (CFS) | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 6/25/97 | 5721 | 7,600 | 0.0076 | 0.0865 | 0.0941 | 0.0118 | 0.1793 | 0.1911 |
| 7/15/97 | 759 | 5,000 | 0.0097 | 0.0885 | 0.0982 | 0.0122 | 0.1969 | 0.2091 |
| 8/19/97 | 3,153 | 5,000 | 0.0178 | 0.1050 | 0.1228 | 0.0242 | 0.2310 | 0.2552 |
| 9/23/97 | | 3700 | 0.0200 | 0.1140 | 0.1340 | 0.0230 | 0.2061 | 0.2291 |
| 10/22/97 | | 3200 | 0.0116 | 0.1750 | 0.1866 | 0.0150 | 0.2865 | 0.3015 |
| 6/17/98 | | 44900 | 0.0158 | 0.4470 | 0.4628 | 0.0526 | 1.4400 | 1.4926 |
| 11/2/98 | | 3600 | 0.0186 | 0.1500 | 0.1686 | 0.0238 | 0.2490 | 0.2728 |
| Average | | 11,567 | 0.0138 | 0.1693 | 0.1831 | 0.0231 | 0.4233 | 0.4464 |

### Ohio River Mile 264

| Date sampled | Flowsed Flow (CFS) | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/16/97 | 16,133 | 19000 | 0.0027 | 0.0140 | 0.0167 | 0.0184 | 0.3176 | 0.3360 |
| 8/20/97 | 82,121 | 62700 | 0.0020 | 0.0098 | 0.0118 | 0.0152 | 0.5160 | 0.5312 |
| 9/24/97 | | 14500 | <0.00099 | 0.0080 | 0.0085 | 0.0131 | 0.2683 | 0.2814 |
| 6/18/98 | | 93700 | <0.00260 | 0.0697 | 0.0710 | 0.0473 | 1.7195 | 1.7668 |
| 11/3/98 | | 9100 | 0.0025 | 0.0043 | 0.0068 | 0.0119 | 0.0888 | 0.1007 |
| Average | | 47475 | 0.0018 | 0.0254 | 0.0270 | 0.0235 | 0.7054 | 0.7289 |

### Ohio River Mile 281.5

| Date sampled | Flowsed Flow (CFS) | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/17/97 | 18,557 | 21,300 | 0.0054 | 0.0323 | 0.0377 | 0.0165 | 0.2965 | 0.3130 |
| 8/21/97 | 69,105 | 68,800 | 0.0033 | 0.0443 | 0.0476 | 0.0135 | 0.8920 | 0.9055 |
| 9/25/97 | | 17600 | <0.00086 | 0.0306 | 0.0310 | 0.0073 | 0.2469 | 0.2542 |
| 6/19/98 | | 175400 | 0.0071 | 0.1360 | 0.1364 | 0.0466 | 1.2900 | 1.3366 |
| 11/4/98 | | 15900 | 0.0080 | 0.0236 | 0.0240 | 0.0183 | 0.1010 | 0.1193 |
| Average | | 70,775 | 0.0041 | 0.0608 | 0.0632 | 0.0210 | 0.6814 | 0.7023 |

### Ohio River Mile 302.9

| Date sampled | Flowsed Flow (CFS) | NWS Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 7/18/97 | 16,829 | 20,400 | 0.0059 | 0.0294 | 0.0353 | 0.0118 | 0.1996 | 0.2114 |
| 8/22/97 | 47,885 | 61,300 | <0.00040 | 0.0440 | 0.0442 | 0.0117 | 0.4830 | 0.4947 |
| 9/26/97 | | 21800 | 0.0049 | 0.0180 | 0.0229 | 0.0156 | 0.1169 | 0.1325 |
| 6/20/98 | | 103900 | 0.0071 | 0.1600 | 0.1671 | 0.0529 | 0.7330 | 0.7859 |
| 11/5/98 | | 17600 | 0.0065 | 0.0190 | 0.0255 | 0.0164 | 0.0909 | 0.1073 |
| Average | | 51,850 | 0.0059 | 0.0629 | 0.0674 | 0.0230 | 0.3831 | 0.4061 |

### Guyandotte River Mile 1.1

| Date sampled | Flowsed Flow (CFS) | Flow (CFS) | 2,3,7,8 TCDD pg/L (ppq) | | | Dioxin TEQ pg/L (ppq) | | |
|---|---|---|---|---|---|---|---|---|
| | | | Dissolved | Particulate | Total | Dissolved | Particulate | Total |
| 12/16/98 | | 1,200 | <0.00018 | <0.00083 | <0.00101 | 0.0078 | 0.2480 | 0.2558 |
| 3/17/99 | | 6,600 | 0.0010 | 0.0191 | 0.0201 | 0.0046 | 0.2930 | 0.2976 |
| Average | | | 0.0005 | | | | | |

Non-detects reported as less than the detection limit (1/2 detection limit used for all calculations).

# Appendix B. Potential Dioxin Sources in the Ohio River Basin.

| | SOURCE TYPE | SITE NAME | LOCATION | COMMENTS |
|---|---|---|---|---|
| 1 | Cement Kiln | Lafarge | Grand Chain, IL | Does not burn hazardous waste. |
| 2 | Medical Waste Incinerator | Western Baptist Hospital | Paducah, KY | Facility is permitted for dioxin emissions. |
| 3 | Hazardous Waste Incinerator | LWD, Inc. | Calvert City, KY | Facility near the Ohio and Tennesse Rivers. |
| 4 | Hazardous Waste Incinerator | Atochem | Calvert City, KY | Near the Tennessee R. |
| 5 | Sewage Sludge Incinerator | Decatur STP | Decatur, IL | Facility is west of the Ohio River Basin. |
| 6 | Secondary Copper Smelting | RECONTEK | Newman, IL | Not close to major tribs. |
| 7 | Hazardous Waste Incinerator | Eli Lily Corp. | Clinton, IN | Near the Wabash R. |
| 8 | Medical Waste Incinerator | Welborn Baptist Hospital | Evansville, IN | Near the Ohio River. |
| 9 | Medical Waste Incinerator | St. Mary's Med. Center | Evansville, IN | Near theOhio River. |
| 10 | Medical Waste Incinerator | Community Methodist Hospital | Henderson, KY | Facility is permitted for dioxin emissions, but not expected to generate dioxin. |
| 11 | Wood Treating Facility | Koppers Industries, Inc. | Guthrie, KY | Not close to any major tribs. |
| 12 | Medical Waste Incinerator | B.G. - Warren Co. Hospital | Bowling Green, KY | Facility is permitted for dioxin emissions, but not expected to generate dioxin. |
| 13 | Recycle Paper Facility | Scott Paper Co. | Newman, KY | Discharges to the Ohio and Green Rivers. Monitoring requirement for dioxin. |
| 14 | Pulp & Paper Mill | Willamette Industries | Hawesville, KY | Discharges to the Ohio R. Monitoring requirement for dioxin. |
| 15 | Cement Kiln | Lehigh Portland Cement | Mitchell, IN | Does not burn hazardous waste. Site near the East Fork White River. |
| 16 | Cement Kiln | Lone Star Industries | Greencastle, IN | Burns hazardous waste. Site is near the Eel River. |
| 17 | Storage Facility | Wedzeb Enterprises, Inc. | Lebanon, IN | Stored electrical transformers. Confirmed groundwater, sediment and soil contamination. |
| 18 | Hazardous Waste Incinerator | Eli Lily Corp. | Lafayette, IN | Near the Wabash R. |
| 19 | Cement Kiln | Essroc Logansport Corp. | Logansport, IN | Burns hazardous waste. |
| 20 | Sludge Incinerator | Indianapolis Sludge Incinerator | Indianapolis, IN | Near the Wabash R. |
| 21 | Hazardous Waste Incinerator | Reily Industries | Indianapolis, IN | Near the White R. |
| 22 | Hazardous Waste Incinerator | OgdenMartin Systems | Indianapolis, IN | Monitors for dioxin. Site near the White R. |
| 23 | Copper Wire Incinerator | The Kroot Corp. | Columbus, IN | |
| 24 | Cement Kiln | Essroc Materials | Speed, IN | Does not burn hazardous waste. |
| 25 | Hazardous Waste Incinerator | Rohm | Louisville, KY | Near the Ohio R. |
| 26 | Cement Kiln | Kosmos Cement | Kosmosdale, KY | Does not burn hazardous waste. |
| 27 | Hazardous Waste Incinerator | Dupont | Louisville, KY | Near the Ohio R. |
| 28 | Cement Kiln | Solite | Brooks, KY | Burns hazardous waste. |
| 29 | Wood Treating Facility | James Graham Brown Foudation | Louisville, KY | Facilty near the Ohio R. |
| 30 | Hazardous Waste Incinerator | Smiths Farm | Shepherdsville, KY | Near the Salt R. |
| 31 | Cement Kiln | Environment | Brooks, KY | Does not burn hazardous waste. |
| 32 | Hazardous Waste Incinerator | Olin Corp. | Brandenburg, KY | Near the Ohio R. |
| 33 | Medical Waste Incinerator | Taylor Co. Hospital | Campbellsville, KY | Facility is permitted for dioxin emissions. Not close to any major tribs. |
| 34 | Medical Waste Incinerator | Westlake Cumberland Hospital | Columbia, KY | Facility is permitted for dioxin emissions. Not close to any major tribs. |
| 35 | Hazardous Waste Incinerator | US Lexington | Richmond, KY | |
| 36 | Medical Waste Incinerator | University of Kentucky | Lexington, KY | Site is not near any major tribs. |
| 37 | Sewage Sludge Incinerator | Cynthiana WWTP | Cythiana, KY | Near the South Fork of the Licking R. |
| 38 | Hazardous Waste Incinerator | Atochem | Carrollton, KY | Near the Ohio R. |
| 39 | Refuse Incinerator | U.S. Army Proving Ground | Madison, IN | Near the Ohio R. Not certain type of materials burned. |
| 40 | Medical Waste Incinerator | St. John's Health System | Anderson, IN | Near the White R. |
| 41 | Wire Insulation Incinerator | DASCO, Inc. | Elwood, IN | |
| 42 | Secondary Copper Refinery | Essex Group | Marion, IN | |
| 43 | Wood Treating Facility | Koppers Company, Inc. | Cincinnati, OH | Facility is inactive. Confirmed on-site soil contamination. |
| 44 | Sewage Sludge Incinerator | Kenton Co. | Fort Wright, KY | |
| 45 | Hazardous Waste Incinerator | Monsanto | Addyston, OH | Near the Ohio R. |
| 46 | Sewage Sludge Incinerator | Millcreek | Cincinnati, OH | |
| 47 | Landfill | Skinner Landfill | West Chester, OH | Located near Mill Creek. Confirmed liquid sludge contamination. |
| 48 | Wastewater Treatment Plant | Middletown WWTP | Middletown, OH | Treats wastewater from Sorg Pulp & Paper Co. Discharges to G. Miami River. |

## Appendix B. Potential Dioxin Sources in the Ohio River Basin.

| | SOURCE TYPE | SITE NAME | LOCATION | COMMENTS |
|---|---|---|---|---|
| 49 | Pulp & Paper Mill | Baywest | Middletown, OH | Facility discharges to the Great Miami River. |
| 50 | Sewage Sludge Incinerator | Little Miami WWTP | Cincinnati, OH | Near the Little Miami R. |
| 51 | Iron Sintering Plant | AK Steel Co. | Midletown, OH | Near the Great Miami R. |
| 52 | Paper Mill | Miami Papers | Franklin, OH | Does not use chlorine. Facility near the G. Miami R. |
| 53 | Paper Mill | Appleton Papers | Franklin, OH | Does not use chlorine. Facility near the G. Miami R. |
| 54 | Sewage Sludge Incinerator | Warren Co. | Franklin, OH | Near the Great Miami R. |
| 55 | Wood Treating Facility | Cowan Lake State Park | Clinton County, OH | Confirmed soil cotamination from inactive wood treating facility. |
| 56 | Municipal Waste Incinerator | Montgomery Co. (South) Incinerator | Dayton, OH | Near the G. Miami R. |
| 57 | Municipal Waste Incinerator | Montgomery Co. (North) Incinerator | Dayton, OH | Near the G. Miami R. |
| 58 | Cement Kiln | Southdown | Fairborn, OH | Facility burns hazardous waste. |
| 59 | Municipal Waste Incinerator | Miami County Incinerator | Troy, OH | Located on the Great Miami River. Confirmed sediment contamination of unamed creek. |
| 60 | Hazardous Waste Incinerator | BP Chemical | Lima, OH | Facility north of the Ohio R. Basin |
| 61 | Cement Kiln | National | Carey, OH | Does not burn hazardous waste. Facility north of the Ohio R. Basin. |
| 62 | Municipal Waste Incinerator | Columbus MWI | Columbus, OH | Site is no longer active. |
| 63 | Sewage Sludge Incinerator | Jackson Pike WWTP | Columbus, OH | |
| 64 | Sewage Sludge Incinerator | Columbus (South) | Columbus, OH | |
| 65 | Hazardous Waste Incinerator | PPG Industries | Circleville, OH | Near the Scioto R. |
| 66 | Pulp & Paper Mill | Mead Corp. | Chilicothe, OH | Facility uses chlorine. Discharges to Paint Cr. |
| 67 | Landfill | Triangle Landfill | South Salem, OH | Received potentially contaminated sludge from Mead Paper. |
| 68 | Landfill | Basic Concrete | Chilicothe, OH | Back-filled quarry pit with potentially contaminated sludge from Mead Paper. |
| 69 | Wastewater Treatment Plant | Wellston WWTP | Wellston, OH | Confirmed sludge contamination. Remedial action was taken. |
| 70 | Chemical Manufacturer | Aristech | Haverhill, OH | Facility near the Ohio River. |
| 71 | Hazardous Waste Incinerator | Dow Chemical | Ironton, OH | Near the Ohio River. |
| 72 | Medical Waste Incinerator | Kings Daughters Hospital | Ashland, KY | Permitted for dioxin emissions. Facility near the Ohio R. |
| 73 | Medical Waste Incinerator | Medisin, Inc. | Prestonburg, KY | Permitted for dioxin emissions. Near the Levisa Fork of the Big Sandy R. |
| 74 | Sewage Sludge Incinerator | Huntington | Huntington, WV | Near the Ohio R. |
| 75 | Chemical Manufacture | Holder Chemical | Ona, WV | No soil contamination. Low levels of dioxin found in fish. |
| 76 | Landfill | South Charleston Landfill | South Charleston, WV | Disposal site 2,4,5-TCP production facility. No soil contamination found. |
| 77 | Chemical Manufacture | Union Carbide | South Charleston, WV | 2,4,5-TCP production facility. No soil contamination found. |
| 78 | Hazardous Waste Incinerator | Union Carbide | South Charleston, WV | Near the Kanawha R. |
| 79 | Chemical Manufacturer | Dupont Belle Plant | Belle, WV | Located on the Kanawha River. Accepted organic wastes from 1926-1977. |
| 80 | Landfill | George's Creek Landfill | Madden, WV | Landfill located on George's Creek near the Kanawha R. Accepted Monsanto waste. |
| 81 | Landfill | Holmes & Madden Landfill | Charleston, WV | |
| 82 | Landfill | Clark Property | Dunbar, WV | |
| 83 | Hazardous Waste Incinerator | Union Carbide (Rhone Poulenc) | Institute, WV | Near the Kanawha R. |
| 84 | Landfill | Don's Disposal | Charleston, WV | |
| 85 | Landfill | Western Kanawha Landfill | Cross Lanes, WV | |
| 86 | Landfill | Nitro Dump | Nitro, WV | Confirmed soil contamination. |
| 87 | Chemical Manufacture | Fike (Artel) Chemicals | Nitro, WV | Confirmed soil contamination. |
| 88 | Landfill | Avtex Landfill | Nitro, WV | Located on the Kanawha River. |
| 89 | Chemical Manufacturer | Flexsys/Solutia (Monsanto) | Nitro, WV | Located on the Kanawha River. |
| 90 | Landfill | Old Monsanto Landfill (I-64) | Nitro, WV | Located on the Kanawha River. Confirmed soil contamination. |
| 91 | Landfill | AES/Monsanto (Solutia) | Nitro, WV | Confirmed soil contamination. |
| 92 | Landfill | Midwest Steel Landfill | Nitro, WV | Landfill adjacent to Armour Creek. |
| 93 | Landfill | Flexsys Armour Creek Landfill | Nitro, WV | Landfill adjacent to Armour Creek. |
| 94 | Landfill | Fleming Landfill | Poca, WV | |
| 95 | Landfill | Poca Strip Mine Landfill | Poca, WV | Confirmed soil contamination. |
| 96 | Landfill | Heizer Creek Landfill | Poca, WV | Dump site along Heizer Creek. Confirmed soil contamination. |

## Appendix B. Potential Dioxin Sources in the Ohio River Basin.

| | SOURCE TYPE | SITE NAME | LOCATION | COMMENTS |
|---|---|---|---|---|
| 97 | Landfill | Manilla Creek Landfill | Poca, WV | Dump site along Manila Creek. Confirmed soil contamination. |
| 98 | Railcar Repair & Maintenance | American Car & Foundary | Winfield, WV | Confirmed soil contamination. |
| 99 | Hazardous Waste Incinerator | Dupont | Parkersburg, WV | Near the Ohio R. |
| 100 | Hazardous Waste Incinerator | Shell Chemical | Belpre, OH | Near the Ohio R. |
| 101 | Wood Treating Facility | Tomkins Industries | Malta, OH | Confirmed soil contamination. Facility near the Ohio River. |
| 102 | Chemical Manufacture | Dover Chemical | Dover, OH | Confirmed contamination. Facility near Sugar Cr. |
| 103 | Chemical Manufacture | PPG | Barberton, OH | Confirmed contamination. Facility near the Tuscarawas R. |
| 104 | Municipal Waste Incinerator | Akron MWI | Akron, OH | Not close to major tribs |
| 105 | Sewage Sludge Incinerator | Akron WWTP | Akron, OH | Not close to major tribs. |
| 106 | Sewage Sludge Incinerator | Canton WWTP | Canton, OH | Not close to major tribs |
| 107 | Chemical Manufacturer | Union Carbide | Marietta, OH | Confirmed soil contamination. Facility near the Ohio River. |
| 108 | Hazrdous Waste Incinerator | American Cyanamid | Willow Island, WV | Near the Ohio River. |
| 109 | Hazardous Waste Incinerator | OSI Special | Sisterville, WV | Near the Ohio R. |
| 110 | Hazardous Waste Incinerator | Miles, Inc. | New Martinsville, WV | Near the Ohio R. |
| 111 | Iron Sintering Plant | Wheeling - Pittsburgh Steel | East Steubenville, W | Near the Ohio R. |
| 112 | Iron Sintering Plant | Wierton Steel | Weirton, WV | Near the Ohio R. |
| 113 | Hazardous Waste Incinerator | Waste Technologies Industries | East Liverpool, OH | Air emissions monitored for dioxin. Facility near the Ohio R. |
| 114 | Hazardous Waste Incinerator | LTV Steel | Warren, OH | |
| 115 | Iron Sintering Plant | WCI Steel | Warren, OH | |
| 116 | Sewage Sludge Incinerator | Youngstown WWTP | Youngstown, OH | Not close to major tribs. |
| 117 | Transformer Manufacturer | Westinghouse Electric Corp. | Sharon, PA | Located near Shenango River. Confirmed groundwater contamination. |
| 118 | Cement Kiln | Essroc Mate | Bessemer, PA | Does not burn hazardous waste. |
| 119 | Cement Kiln | Cemtech Cement Co. | Wampum, PA | Burns hazardous waste. |
| 120 | Sewage Sludge Incinerator | Ambridge STP | Ambridge, PA | Near the Ohio R. |
| 121 | Chemical Manufacture | Ohio River Park Superfund Site | Neville Island, PA | Located on the Ohio River. Confirmed soil contamination. |
| 122 | Cement Kiln | Armstrong Cement & Supply | Cabot, PA | Does not burn hazardous waste. |
| 123 | Cement Kiln | Kosmos Cement | Pittsburgh, PA | Does not burn hazardous waste. |
| 124 | Sewage Sludge Incinerator | Alcosan WWTP | Pittsburgh, PA | Near the Ohio R. |
| 125 | Cement Kiln | Lafarge | Whitehall, PA | Does not burn hazardous waste. |
| 126 | Cement Kiln | Hercules | West Elizabeth, PA | Does not burn hazardous waste. |
| 127 | Municipal Waste Incinerator | Wheelabrator | Morrisville, PA | |
| 128 | Sewage Sludge Incinerator | Clarksburg STP | Clarksburg, WV | Not close to major tribs. |
| 129 | Hazardous Waste Incinerator | Ordnance | Morgantown, WV | |
| 130 | Hazardous Waste Incinerator | Neville Chemical | Pittsburgh, PA | Near the Ohio R. |
| 131 | Sewage Sludge Incinerator | Kiski VAlley Water Pollution Control | Leechburg, PA | |
| 132 | Sewage Sludge Incinerator | Kiski Valley WP | Apollo, PA | Near the Kiskiminetas R. |
| 133 | Municipal Waste Incinerator | Westmoreland MWI | Greensburg, PA | Not close to major tribs. |
| 134 | Sewage Sludge Incinerator | City of Johnstown | Johnstown, PA | Facility on eastern edge of basin. |
| 135 | Pulp & Paper Mill | Penntech Papers, Inc. | Johnsonburg, PA | Facility uses chlorine in bleaching process. |

Data compiled from the following sources:
National Dioxin Study (EPA, 1987)
Quantitative Estimation of the Entry of Dioxins, Furans and Hexachlorobenzene from Airborne and Waterborne Sources (Cohen and associates, 1995)
Dioxin TMDL Development for Kanawha River, Pocatalico River, and Armour Creek, West Virginia Draft (LTI for US EPA Region III, 1999)
Information requests to state officials from Pennsylvania, Ohio, West Virginia, Kentucky, Indiana and Illinois (1995/1996).