PRECISION POINT

To: Dr. McAvoy

From: Bethany Caspersz, Matthew Cummings, Dexter Adams, Qianhui Xia

RE: GCWW Capstone Project Proposal
Date: April 15, 2019

Dear Dr. McAvoy,

Precision Point is honored to present the final project report l for determining the extent of lateral dispersion in the Ohio River:Combs-Hehl Bridge to the Little Miami River confluence.

Attached includes:

- Literature review of 3D models for computational fluid dynamics and chemical transport modeling
- Alternative analysis of the top 3D models
- Recommendation of the 3D model best equipped for the project scope
- Development of the 3D model in the recommended software
- Model results and analysis of the extent of lateral dispersion in the Ohio River study area
- Recommendation of the optimized drainage diversion location along the Combs-Hehl bridge

Precision Point is excited to offer design and modeling services for the completion of this design proposal and is available to provide further information or guidance if needed. Thank you for your consideration of Precision Point.

Respectfully Submitted,

Bethany Caspersz
Matthew Cummings
Dexter Adams
Qianhui Xia

Determining the Extent of Lateral Dispersion in the Ohio River:Combs-Hehl Bridge to the Little Miami River Confluence (Ohio River Miles 461.9 to 463.3)

University of Cincinnati Environmental Engineering
Senior Design Project

PRECISION POINT

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4.19.2018

Executive Summary

The project goal was to mitigate the risk of a hazardous spill from the Combs-Hehl Bridge, located only .86 miles upstream of the Greater Cincinnati Water Works (GCWW) and the Northern Kentucky Water District (NKWD). The hazardous pollutant could potentially reach intakes of both water districts within 15 minutes of the initial spill. Our team has determined an optimal location along the Combs-Hehl bridge where the downspouts will direct flow into the river at a distance far enough from the GCWW and NKWD water intakes so that a spill would flow past the intakes and not be pulled into the treatment plants.

This determination was based on the results of a 3D computational fluid dynamics (CFD) model. A total of eight CFD models were evaluated for fitness to the scope of the project based on the following criteria: availability of professional guidance, a graphical user interface (GUI) for ease of use, and flexible post-processing for customizable output of the model results. An extensive alternative analysis revealed that the CFD software Flow-3D was the most adept for the needs of this project. As part of this project a dye study was conducted in October 2018 to obtain real-world data for the calibration of the Flow-3D model. Data collected from the dye study included bathymetry of the river study area, velocity profiles, and measured concentrations of the dye. The model was run at the 10th percentile flow (30,000 cfs), median flow (91,900 cfs), and 90th percentile flow (200,000 cfs). The Flow-3D results showed that the higher the flow rate of the river, the less lateral dispersion of the pollutant would take place within the river reach under study. The optimal bridge downspout location was determined to be 327 ft from the Ohio side, using the median flow rate of the river.

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1. Introduction

1.1. Site Background – The Ohio River is the source of water for most businesses and city utilities in the Cincinnati and Northern Kentucky region. Both Cincinnati and Northern Kentucky have water treatment plants pumping source water from the Ohio River. Greater Cincinnati Water Works (GCWW) treats 240 million gallons of water per day, and the Northern Kentucky Water District (NKWD) treats 44 million gallons of water per day. The intakes for each treatment plant are located upstream of downtown Cincinnati, near California, OH. These intakes are 0.86 miles downstream of the Combs-Hehl Bridge, shown in Figure 1. The project study area, location of both intakes, and the Combs-Hehl Bridge are displayed in Figure 2.

Figure 1: Combs Hehl Bridge located on I-275, California, OH

Figure 2: Project Study Area Displaying Treatment Plant's Intake Locations

1.2. Scope of Issue – A regional water protection program called the Ohio River Source Water Alliance (ORSWA) has been created through collaboration with GCWW, NKWD, and the Ohio River Valley Water Sanitation Commission (ORSANCO). The primary objective of this Alliance is to identify and mitigate risks to the quality of source drinking water. ORSWA has identified the Combs-Hehl Bridge as a high priority potential source of contamination in the Ohio River because statistics show that up to 10 trucks per hour carry DOT listed hazardous materials cross the bridge. This scenario poses a large threat to both GCWW and NKWD. Flow of the river can range from 0.5 mph to 4 mph, so materials spilled in the river could reach both intakes within 15 minutes to two hours, giving very little time for the water treatment plants to react. Storm water drains are located across the length of the bridge, so currently a spill could enter the Ohio River at any of the points pictured in Figure 3.

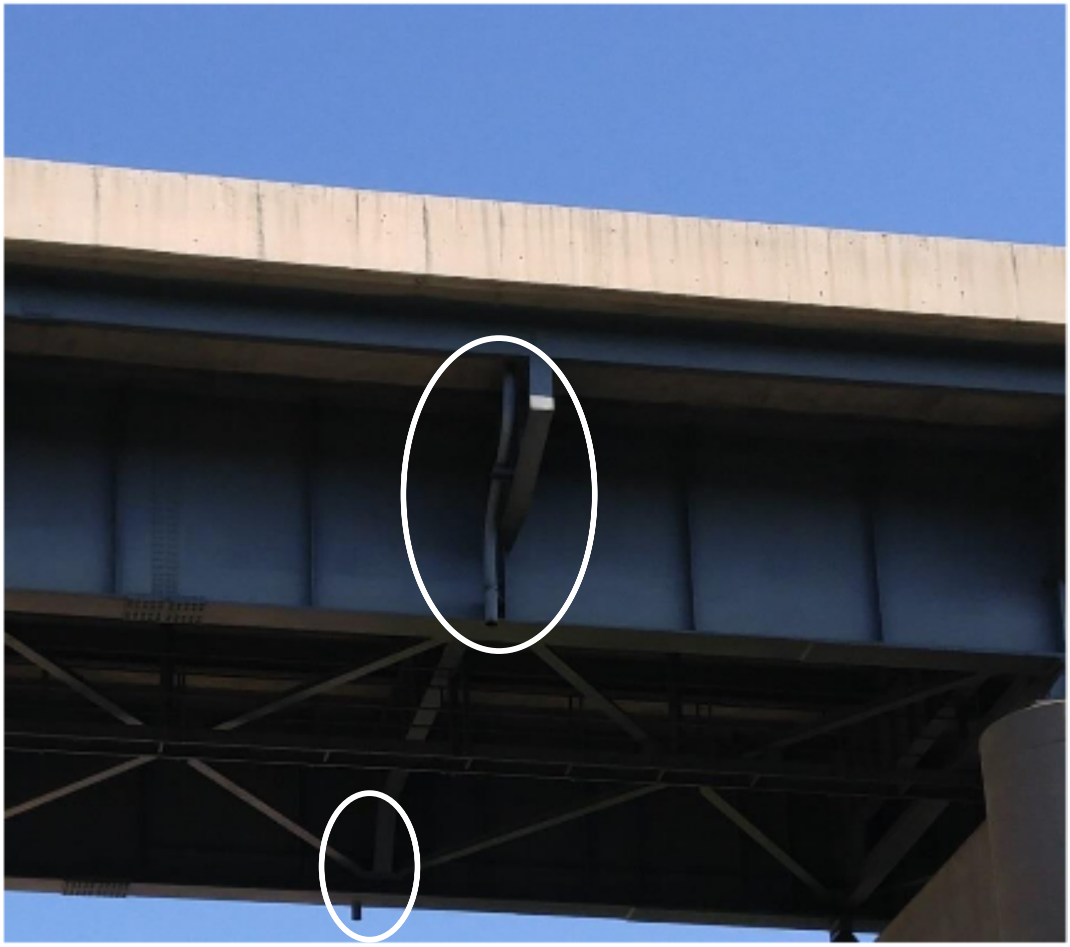

Figure 3: Stormwater Drains Located on the Combs-Hehl Bridge

1.3. Problem Statement – Risk mitigation of source pollution at the GCWW and NKWD water intakes is the main goal of this project. The risk of a spill from the Combs-Hehl Bridge reaching the water intakes is reduced by diverting the bridge downspouts to the Ohio side of the river, away from the water intakes on the Kentucky side. In order to assess the best location for the discharge from the bridge, a dye study was conducted to measure data of a representative spill. This data was used to calibrate the 3D model simulating a spill in the study area. Once the 3D computational fluid dynamic (CFD) model was built, the model was run under three flow conditions and fifteen bridge downspout locations to determine the optimized spot for diversion of the discharge. The three flow conditions, provided by the USGS, defined 90th percentile flow, (200,000 cfs), the median flow, (91,900 cfs), and 10th percentile flow, (30,000 cfs).

1.3.1. Dye Study – Dye tests were performed on October 22, 2018 and October 23, 2018. A report was prepared by GCWW summarizing these results which is located in Appendix A. The purpose of the dye study was to simulate a potential spill scenario and calibrate a 3D model from experimental data. Rhodamine WT was used as a tracer in this study. A fluorometer was used to measure the dye concentrations in relative fluorescent units as the plume navigated downstream and towards the GCWW and NKWD intakes. Other parameters were measured throughout the experiment such as the bathymetry and velocity of the river. The dye plume moving down the river can be seen in Figure 4, additional pictures from the dye study can be found in Appendix A.

Figure 4: Dye plume flowing downstream towards the GCWW intake

1.3.2. Model Investigation – Precision Point's role was to select a 3D model to simulate dispersion of contaminants in the lateral and longitudinal directions of the study area. The most important criteria for selecting our model was the availability of professional guidance, a graphical user interface (GUI) for ease of use, and flexible post-processing for customizable output of the model results. Examples of output generated from the 3D models investigated can be found in Appendix B. Research in this report assessed different 3D models identified by the team: HEC-RAS, CHEMMAP, WASP, EFDC, Delf3D, OpenFOAM, ANSYS Fluent, and Flow-3D. Our team ultimately recommended the 3D model best equipped to achieve the goals of GCWW and ORSWA.

1.3.3. Three-dimensional Modeling for the Ohio River – A 3D simulation was created using the CFD software based on the recommendation established in sections 1.3.2 of this report. The bathymetry data recorded during the dye study was used to build a 3D shapefile of the bed of the Ohio River. Precision Point used Rhino3D, a commercial computer-aided design (CAD) software developed by Robert McNeel & Associates, to create the shapefile from the bathymetry data. This shapefile was inputted into Flow-3D to provide the model with necessary dimensions of the study area and to define the fluid region where flow would be simulated. Data gathered from the dye study, such as dye concentrations and velocity profiles, were used to calibrate the Flow-3D model. Then, the model was repeated varying the flow conditions and the location along the Combs-Hehl bridge where the contaminant enters the system to represent various downspout locations.

2. Comparison of Alternatives

2.1. Potential Models and Initial Screening – Precision Point identified eight software systems that could potentially meet the scope of this report; HEC-RAS, a River Analysis System, CHEMMAP, a chemical spill model, WASP, a Water Quality Analysis Simulation Program, EFDC, an Environmental Fluid Dynamics Code, Delft3D, a 3D modeling suite investigating hydrodynamics and water quality, OpenFOAM, an open source Field Operation and Manipulation software, ANSYS Fluent, a CFD software capable of modeling laminar and turbulent flow. Flow-3D is a CFD software specializing in transient, free surface flows. Several of these models were initially screened out of contention due to their limitations in 3D CFD modeling or cost of proprietary licenses. The remaining top three model choices include OpenFOAM, ANSYS Fluent, and Flow-3D.

2.1.1 OpenFOAM – OpenCFD Ltd developed an open source Field Operation and Manipulation software, OpenFOAM, which is capable of solving complex fluid flows involving chemical reactions, turbulence, heat transfer and more. OpenFOAM operates through a C++ toolbox for developing and customizing numerical solvers, and pre-/post- processing utilities for solving computational fluid dynamic problems. Through literature review of OpenFOAM's application, the team determined that this software is a high contender in being able to generate 3D results that can be easily visualized to meet the scope of the capstone project. However, the main drawbacks from this software lie in its pre-/post- processing capabilities. OpenFOAM requires the use of other software or Graphical User Interfaces (GUI's) to pre-process the geometry and an additional software to post-process the results into a three-dimensional visualization. Even though OpenFOAM has intensive computational requirements, this open source software remains as a participant in the alternative analysis due to its robust CFD and transport solvers along with its flexibility and customizability due to its open source nature.

2.1.2 ANSYS Fluent – ANSYS, a developer and marketer of engineering simulation software, developed a CFD software, Fluent, capable of modeling laminar and turbulent flows, chemical reactions, radiation and particulate dynamics. Fluent can model the behavior and interactions of a large number of phases, including a combination of liquid, solid, gas and granular flows. Due to the literature review of ANSYS Fluent applications such as modelling flow and particulate contaminants in urban storm water and simulating pollutant dispersion of a free surface flow, the team determined that the 3D modeling and visualization of results allows Fluent to be a strong potential candidate to meet the objectives of the project, and therefore will be included in the alternative analysis of 3D models.

2.1.3 Flow-3D – Flow-3D is a computational fluid dynamics model developed by Flow Science, Inc. The program is not available on public domain, with all leases coming from Flow Science, Inc.. However, a four-month trial academic version can be obtained. Flow-3D specializes in transient, free surface flows by applying advanced algorithms combined with general flow equations and turbulence modeling. These aspects allow the software to capture trajectory of flow from a spillway, hydraulic jumps, and surface variations formed by flow. Flow-3D's capabilities include river hydraulics, bridge piers, hydraulic zones of influence, contaminant modeling, spillways, fish passages, and dam breaks. Bathymetry and dye study data can be inserted into the software to display a 3D model of the area of study. The Flow-3D model renders easily customizable outputs to visually depict various hydraulic parameters of the simulation, outcompeting all other models under study.

2.2. Comparison Technique – To determine which of the 3D models under investigation would be best equipped to meet the goals of GCWW in this capstone project, an alternative analysis was employed. This type of analysis allows an objective approach to determine the fitness of the alternative solutions to a problem. An alternative analysis is performed by first identifying achievable and relevant project goals that the alternative options must execute. Next, a selection criterion is established to determine the feasibility of the alternatives. Then, a scoring system is utilized to determine the objective ranking of the alternatives. Finally, all choices are put into an alternative matrix, scored, and results in one of the alternatives ranking the highest.

In this capstone project, a weighted alternative analysis was conducted through the investigation of the 3D models under study. The weighted method assigns a certain weight to the selection criteria or goals based on the project's scope of work and which selection criteria are deemed more important to execute the the project's goals.

2.3. Criteria of Comparison – The team determined a set of criteria as the basis of comparison for the 3D models under investigation. This method allowed the team to determine which model performed the best within the scope of the various goals of this project.

2.3.1 Visualization – Data visualization and the ease of interpreting results will be extremely important for the end of the project. The goal is that the end user can clearly decipher the results calculated by the model through a visual representation of the river reach under study. Data visualization that allows the user to see changes in concentration over latitudinal and longitudinal dimensions over time would be the ideal results to achieve the goal of the project.

2.3.2 3D Capability – One of the core criteria to represent the goals of the project is that the recommended model can handle three-dimensional computation and three-dimensional output. The capability of 3D modeling is critical for this project due to the latitudinal and longitudinal dispersion of pollutants with respect to the location of the drinking water intake.

2.3.3 Professional Guidance – The team determined that the availability of experienced professionals will set apart the models under investigation, since having this resource will be critical in expediting our analysis, in order for the project to be accomplished on schedule. Additionally, an experienced resource will allow the team to overcome any issues or problems with the model much sooner.

2.3.4 Cost – While investigating the various available 3D models for CFD and transport modeling, it quickly became apparent that the more advanced software required more expensive licenses. The point of the cost criterion is to rank how well the models can perform in the other important aspects in relation to the cost.

2.3.5 Tutorial Availability – Availability of further guidance, tutorials and test cases are extremely important for the scope of the work, since the team is not experienced in using any of the models under study. It will be critical to have guidance to direct the usage and application of these models, and to determine if the achieved results are in fact accurate.

2.3.6 Ease of Use – The ease of use criteria is defined as how intensive the model is to be used by the user. For example, a model with a facilitated GUI would score much higher for the ease of use criteria than a model where coding may be required.

2.3.7 Pre-/Post- Processing Intensiveness – The criterion of pre-/post- processing intensiveness is due to the fact that several of the 3D models under study require other software to generate a mesh for the computation (pre-process), or to render the results in a 3D visualization (post-process). The ideal 3D model would be one that could handle the pre-/post-processing along with the actual computation.

2.4. Alternative Analysis Results

– An alternative analysis was conducted on the top three candidates: Flow-3D, OpenFOAM, and ANSYS Fluent. The ranking of each model was 3 (best) to 1 (worst). The criteria were weighted from 7 (most critical to project scope) to 1 (least critical to project scope) in the following order; 3D Capability, Professional Guidance, Visualization of Results, Cost, Ease of Use, Availability of Tutorials, and Pre-/Post- Processing Intensiveness. The detailed alternative analysis matrix can be found in Appendix C.

Table 1 shows the scoring of the top three 3D models based on the team's professional opinions formed by the extensive research conducted on each of the individual models. The literature review research formed the opinions for the scoring based on the visualization of the outputs generated and input conditions needed. Since OpenFOAM is an open source software, the team was able to familiarize with this program and score its capabilities. The maximum score for the pre-weighted analysis is 21, while the max score for the weighted analysis is 84. Out of the three models analyzed, Flow-3D scored highest with both the pre-weighted score, 19, and the weighted score, 78. ANSYS Fluent scored second with both pre-weighted and weighted scores, 15 and 64, respectively. Lastly, OpenFOAM scored the lowest with 13 and 51 as the respective pre-weighted and weighted scores.

Table 1: *Weighted alternative analysis of the top three models*

Table 1: Weighted alternative analysis of the top three models

Criteria	Weighting	Flow 3D	OpenFOAM	ANSYS Fluent
Visualization of Results	5	3 (15)	2 (10)	3 (15)
3D Capability	7	3 (21)	2 (14)	3 (21)
Professional Guidance	6	3 (18)	1 (6)	2 (12)
Cost	4	2 (8)	3 (12)	1 (4)
Availability of Tutorials	2	2 (4)	2 (4)	2 (4)
Ease of Use	3	3 (9)	1 (3)	2 (6)
Pre / Post Processing Intensiveness	1	3 (3)	2 (2)	2 (2)
Pre-weighted score		19	13	15
Max Pre-Weighted Score	21			
Weighted Score		78	51	64
Max Weighted Score	84			

3. Recommendation

Based on the alternative analysis, Flow-3D is recommended as the best model to use for this project. Flow-3D's modeling and rendering capabilities make it a clear pick compared to other models previously discussed. A 90-day academic free trial was granted to our team by Flow Science, eliminating any concern for costs the team previously had. Professional guidance will be available to the team through a resource of UC's faculty. This guidance and support will not only benefit creating the model itself, but will be of great assistance when inserting the dye study and bathymetry data. Having strong resources will allow the team to overcome and solve any unforeseeable problems in a quick and timely manner. Furthermore, Flow Science confirmed that Flow-3D can solve the scope of work requested in this specific project.

4. Model Development

4.1. Shapefile of the River Reach Study Area – The dye study yielded several data sets; bathymetry, velocity profiles, dye concentrations, and images as well as real time video coverage of the dye plume. For the first step in developing the model, the team had to create a shapefile of the river reach under study, displayed in Figure 5. This was completed by using the bathymetry dataset from the dye study and the software Rhino 3D. The geographic coordinates in an x, y, z format were converted to Ohio U.S. State Plane Coordinates. Due to size limitations in Rhino 3D on the dimensions in the x, y, and z directions, in addition to the bathymetry coordinates exceeding these dimension limits, flat amounts were subtracted from the easting (1,420,000), northing (388,000), and altitude (400). The U.S. state plane coordinates were then plotted in Rhino 3D, connected into a polygon, smoothed, and extruded into a 3D surface. Next, the shapefile was inputted in Flow-3D, the CFD software recommended and used to complete the goals of this project.

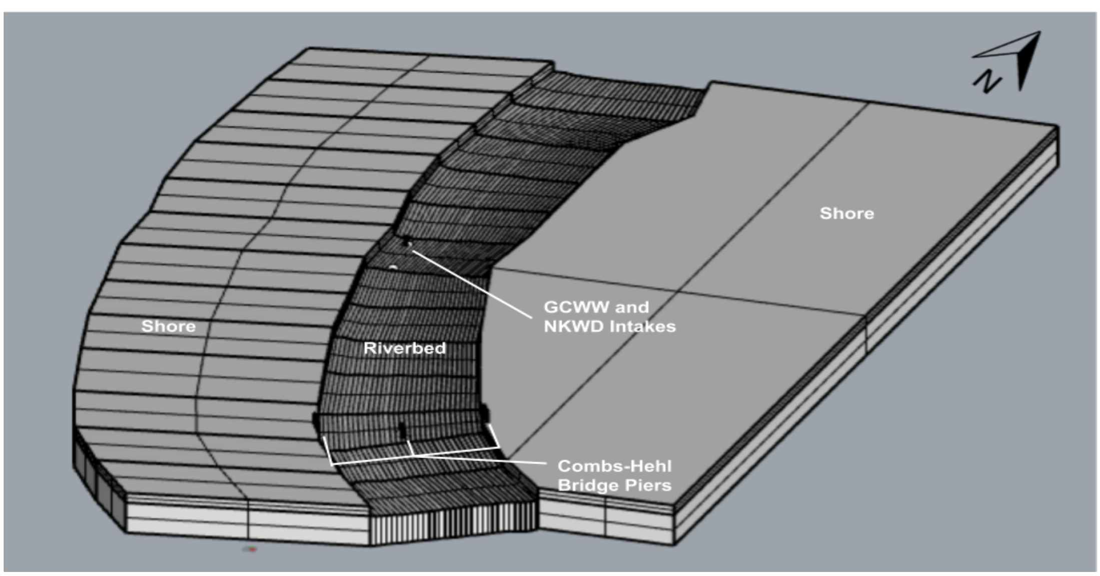

Figure 5. Shapefile of the Ohio River reach study area from Rhino

4.2. Model Setup

4.2.1 Mesh – Once the shapefile defining the workspace was inputted into Flow-3D, the team created the mesh for the development of the region of fluid flow calculations. The mesh is the computational grid of cells where the software makes hydraulics calculations in each individual cell. The refinement of a mesh is based on the number of cells in the computational grid. Where more cells equate to a higher refinement, this also takes more computational time and can become impractical. However, a lower refinement could cause over generalized calculations that are no longer representative of the real flow conditions. The amount of cells was calculated by taking the length of each x, y, z direction divided by the desired size of the cells to determine the number of cells that would fit in each reach. Table 2 below displays the mesh cell dimensions. The mesh was slightly adjusted based on the flow conditions being run in the simulation. For example, the 90th percentile flow has a smaller number of cells to allow the model to complete calculations within a reasonable run time, not exceeding 2 hours. Table 2 also shows that the number of cells in the z-direction is decreased for the 10^{th} percentile low flow to optimize the simulation run times since low flow sees shallower depths than the other flow conditions simulated.

Table 2: *Mesh dimensions per flow condition*

Flow Condition	Flow Rate (cfs)	Plane	Length of Plane (ft)	No. of Cells	Length of Cell (ft)
10th percentile	30,000	x	3450	69	50
		y	9000	180	50
		z	95	34	3
Dye Study	73,000	x	3450	69	50
		y	9000	180	50
		z	100	25	4
Median	91,900	x	3450	69	50
		y	9000	180	50
		z	100	25	4
90th percentile	200,000	x	3450	50	69
		y	9000	180	50
		z	100	20	5

4.2.2 Boundary Conditions – The next step in setting up the model was defining the boundary conditions of each plane of the fluid region. Boundary conditions are an extremely important aspect of CFD modeling since these conditions represent realistic conditions of flow at the boundary location. Most common boundary conditions used in computational fluid dynamics are the inlet conditions, symmetry conditions, physical boundary conditions, pressure conditions, and exit conditions.

The inlet and outlet of the river reach under study were classified as the Y_{min} and Y_{max} planes, respectively. As can be shown by the shapefile in Figure 5, the portion of the river studied is curved, so the angle that the water entered the plane had to be calculated. The software used to build the shapefile, Rhino 3D, has features to analyze dimensions of the shapefile that yielded an angle of water entry of 131°.

The Y_{min} boundary condition was set as a volumetric flow rate. A rating curve, obtained from USGS, was added to the Y_{min} boundary conditions in order to provide the model with values relating the river height and flow rates. The Y_{max} plane representing the exit conditions was set as a stagnation pressure boundary condition. In Flow-3D, a stagnation pressure condition assumes stagnation conditions outside the boundary so that the velocity at the boundary is zero. This assumption requires a pressure drop across the boundary for the computational region.

The X_{min} and X_{max} planes represent the sides of the river and their physical boundaries conditions were both specified as walls. The Z_{min} and Z_{max} planes represent the bottom and top of the river, respectively. Similar to the sides of the river, the bottom of the river, Z_{min}, was classified as a wall condition. At these walls, a no slip boundary condition was used for hydraulic calculations, as can be represented by Figure 6 provided by *Fluid Mechanics Fundamentals and Applications* by Yunus Cengel and John M. Cimbala. Lastly, the Z_{max} plane represents the water surface open to the atmosphere where a symmetry boundary condition was applied. Symmetry boundary conditions apply a zero flux at the boundary with zero friction.

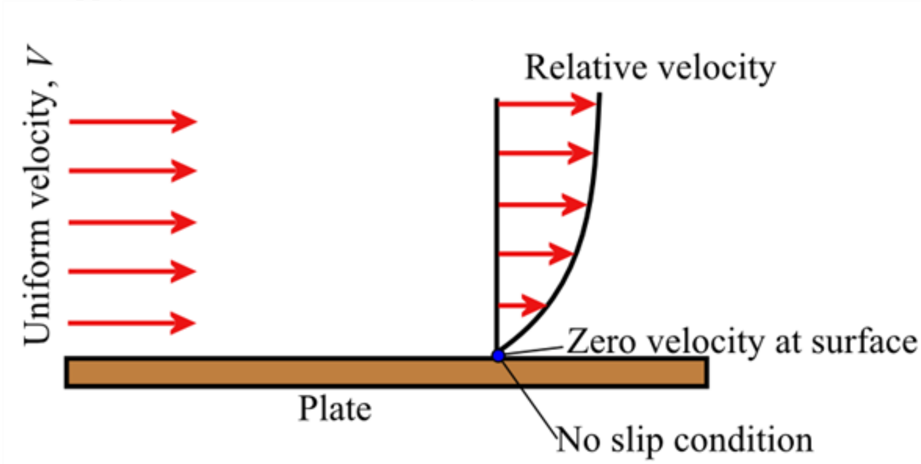

Figure 6. Demonstration of no slip boundary condition (Cengel et al.)

4.2.3 General Model Parameters – The overall physics and numerics used for calculating the hydraulic properties of fluid flow in Flow-3D was the Re-Normalisation Group (RNG) K-epsilon turbulence model, which is derived from the incompressible Navier Stokes equations.

The general model parameters specified in the model setup included viscosity, a diffusion coefficient, a turbulence coefficient, flow rates, and manning's n. Fluid properties, such as density and temperature, were applied through selecting a preset option offered through Flow-3D which defaulted to water at 20℃, a density of 1.94 slugs/ft^3, and a viscosity of 2.89x10^{-5} slug/ft-s.

The diffusion coefficient, which was used when the dye and pollutant were added to the model, impacts the turbulent dissipation transport equation of the contaminant in the fluid. The diffusion coefficient could be manipulated to either slow down or increase the rate of dispersion of the contaminant in the river. A unitless diffusion coefficient of 10 was determined experimentally by comparing the dye concentrations from the dye study to the Flow-3D results. This value was determined by repeating the simulation under a range of diffusion coefficients from 4.3 to 15. The relationship between the dye study concentrations and the Flow-3D results was the most correlated, with a correlation coefficient, r, of .65, when using a diffusion coefficient of 10.

Another parameter built into the model to impact the diffusivity of a contaminant in a fluid is the turbulence coefficient. In our model it was determined to keep the turbulence coefficient at the default value of 0 due to the fact that changing this coefficient increased the run time for the simulation to over 2 days. It would not have been feasible to complete the scope of this project with singular run times of that length, so the team moved forward with the default turbulent coefficient value which allowed for run times varying from 15 minutes to 110 minutes.

The most impactful model parameter was the flow rate. The flow rate was the principle independent variable that was adjusted in repeated simulations of the model to analyze how the concentrations of the dye and the contaminant spill would be impacted at higher and lower flow conditions of the river, principally, the concentrations at the intakes. However, the team experimentally determined that a correction factor was needed for the flow rate because of inaccuracies in representing the river bed shape in the shapefile. The need for a correction factor was realized when comparing the dye study concentrations to the Flow-3D concentration output. When comparing the concentrations at the same geographic points along the river where the samples were measured during the dye study, the Flow-3D simulated concentration results were of the same magnitude but occurred earlier in time than the dye study concentrations. This was due, in part, to the bathymetry data not completely representing the actual river bed and shape. As can be seen in the shapefile in Figure 5, the slope is a sharp 90° angle between the river bed and the shoreline at the very southeast corner. This phenomenon is due to the imperfections of gathering survey data and the way the shape file was extruded in Rhino 3D. The sharp angle between the riverbed and the shoreline causes a portion of the riverbed, whose slope is actually gradually increasing to the shoreline, to be cut off. Owing to the fact that the bathymetry of the river reach under study caused inaccuracies of the fluid region and since the peak dye concentrations of the Flow-3D simulation occurred sooner than the measured dye concentrations, the team determined that Flow-3D modeled the river flow rate faster than it was occurring in reality. Therefore, a correction factor of 0.94 was experimentally determined to calibrate the modeled flow rate to represent the actual flow rate of the Ohio River. The flow rate correction factor was applied to each of the input flow rates henceforth in the model.

Manning's *n* in hydraulics is an empirically derived coefficient that is highly variable, dependent on the bed roughness and sinuosity, and impacted by objects or vegetation in the river. The model experimentally determined the Manning's *n* of the river reach under study by comparing the simulated velocities at 50 points to measured velocities on the day of the dye study using the Acoustic Doppler Current Profiler (ADCP). A Manning's *n* of .035 yielded the strongest correlation to the Flow-3D simulated velocity profile. USGS provides historical verified roughness characteristics (Manning's *n* values) of natural channels ranging for rivers of similar stature to the Ohio River ranging from 0.033 to 0.043, thus a Manning's *n* of 0.035 would be a reasonable assumption to apply to our model.

4.2.4 Steady State Flow Conditions – Since the purpose of the model is to analyze the effect of changing flow rate on the concentrations of a contaminant, it is essential to have conditions where all other fluid properties at any single point in the system do not change over time, otherwise known as steady state conditions. Our system reached steady state when the volumetric flow rate entering the river reach was equivalent to the volumetric flow rate exiting the system. Steady state was critical to achieve so that the model would have consistent flow conditions throughout the entire fluid region. Flow-3D generates graphs, such as what is represented in Figure 7 below, which displays the volumetric flow rate at the outlet, the Y_{max} boundary, with respect to time. Figure 7 represents the time it takes the model to reach steady state, which is known when the exiting flow rate relative to time stops fluctuating and yields a straight line. As shown, the model begins to reach steady state under the dye study flow conditions of 73,000 cfs around 1,800 seconds and by 3,600 seconds, steady state conditions are achieved. It was observed that the higher simulated flow conditions took increasing longer to reach steady state conditions. The time to reach steady state varied from 2000 seconds for low flow conditions, 3,400 seconds for median flow, and 5,200 seconds for high flow conditions.

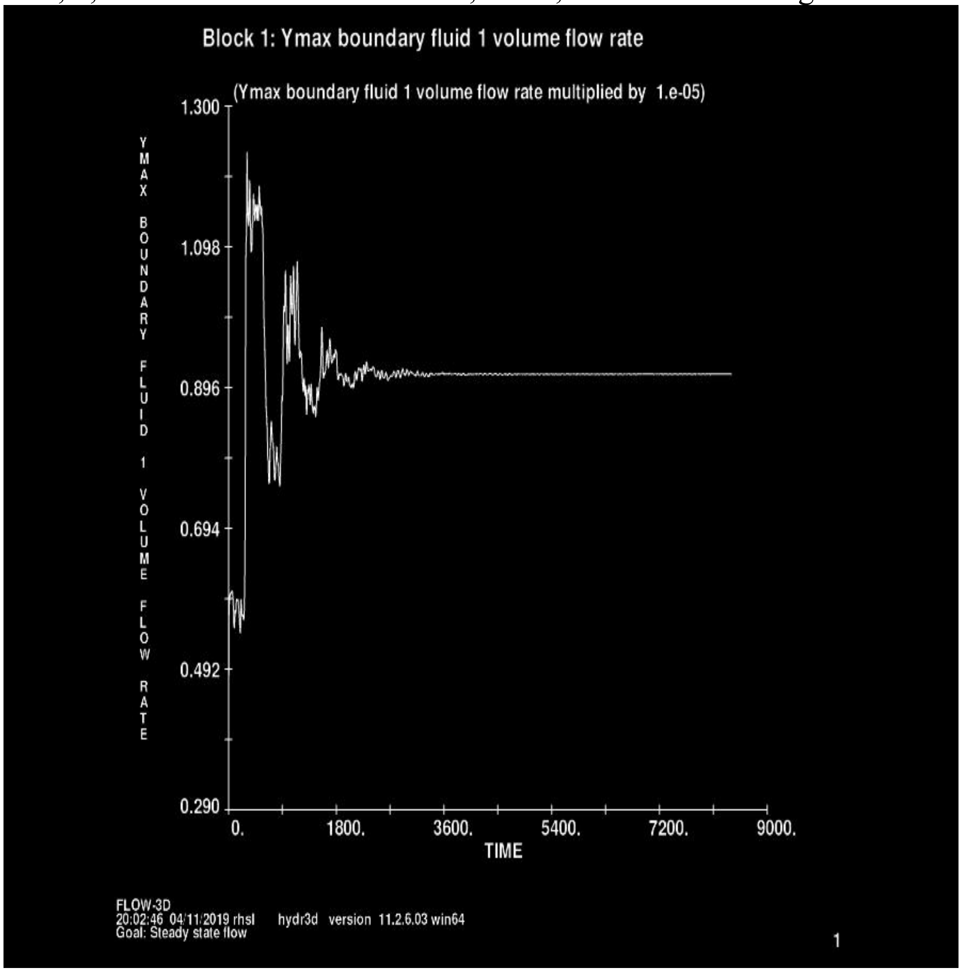

Figure 7. Y_{max} boundary fluid flow rate vs. time in seconds leading to steady state

4.2.5 History Probes and Scalar Insertion – Flow-3D provides measurement devices in order to retrieve the hydraulic data outputs at specific locations in the mesh where calculations are being performed. History probes are point data recorders where flow rates and dye concentrations could be observed at specific geographic points and were inserted throughout the model. The determination of the location of the history probes was based on certain points where data had been measured during the dye study and the principle location of interest, the GCWW intake. The hydraulic output data recorded at the history points can be graphed or exported to Excel. Data measured from the history probes were essential in calibrating the model and comparing the calculated velocities and dye concentrations to the measurements from the dye study.

In Flow-3D, a Scalar model allows user-defined scalar variables, such as density, viscosity, and concentration, to be included in the model's calculations. A scalar was inserted into our model as a mass momentum source representing the dye or pollutant in the different model simulations. First, the initial concentration of the scalar had to be defined. For simulating the dye study, the initial dye concentration was calculated by finding the concentration of the Rhodamine dye used in the entire five-gallon sample that was poured into the river over a 90 second period. The units of concentration used throughout the model's calculations were set to ppb by converting the dye concentration input to 9.4 x 10^7 ppb.

The scalar applied to the model runs simulating a pollutant spill from the Combs-Hehl bridge was different that the scalar applied in the simulation of the dye study by magnitude of volume and concentration. The pollutant was assumed to have the same density and viscosity of water, which simulates a general spectrum of industrial alcohols that would be fairly soluble with water. Since the concern of GCWW is the transport of hazardous materials across the Combs-Hehl bridge, the volume of the potential spill was 9,000 gallons to represent a tanker truck spilling into the river over 600 seconds, or 10 minutes. Precision Point determined the initial concentration of the pollutant spill to represent a pure pollutant of 1 billion ppb. This is the most conservative approach for modeling a worst case scenario of a large concentrated spill.

4.2.6 Calibration of model results to the dye study results – The model was calibrated by matching the geographic locations at which the dye concentrations measured on the day of the dye study to the same coordinate locations and time within the model. Precision Point experimentally determined a maximum of 30 history probes could be used to record such data to match the dye study. Any more history probes than this would cause increased run times that would inhibit completion of the project goals. Figure 8 shows the correlation between dye concentrations by plotting the simulated model output versus the measured concentrations from the dye study, yielding an r of 0.65 (and a corresponding R^2 of 0.4229). This correlation was deemed acceptable by Precision Point due to the fact that the model is working in units of ppb while the dye study measurements were taken in relative fluorescent units (RFU). These units are not a one-to-one relationship, and a conversion factor does not exist without use of a standard curve which relates the concentration of the measured product to the corresponding fluorescence intensity. In addition to not having a conversion factor between units, the lowest value measured during the dye study was an RFU of 36. The team determined this value to represent "background noise" of the river conditions the day of the dye study, so this value was subtracted from all RFU data points in order to achieve a stronger correlation show by Figure 8.

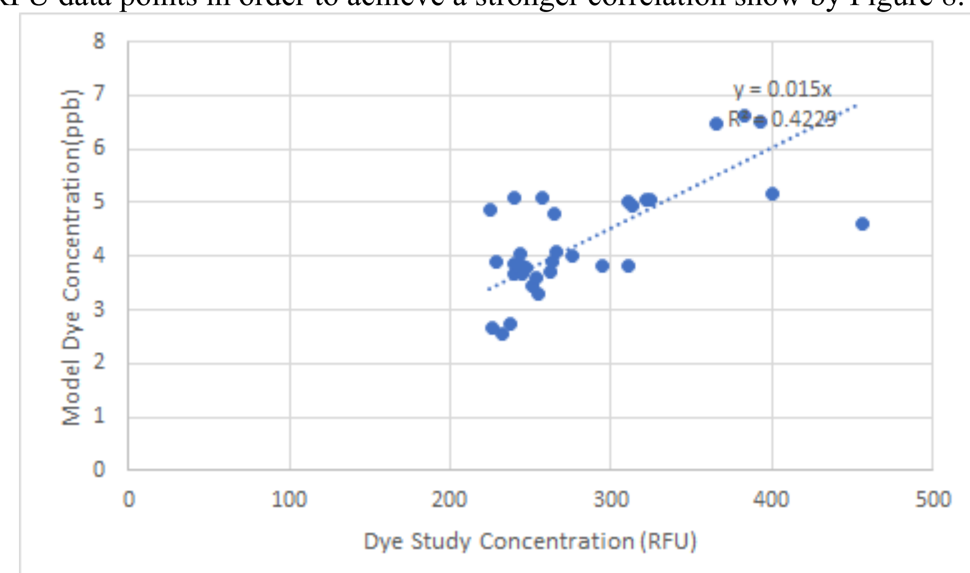

Figure 8. Flow-3D dye concentrations in ppb versus dye study concentrations in RFU

5. Results and Analysis

5.1. Flow Condition Inputs – The model was tested at different flow conditions to highlight the differences in lateral dispersion of the simulated dye and pollutant spill at the intakes. Flow conditions tested included the flow rate on the day of the dye study (73,000 cfs), the 90th percentile flow (200,000 cfs), the median flow (91,900 cfs), and the 10th percentile flow (30,000 cfs). These flow conditions on the Ohio River were provided to the team by USGS data on the Ohio River.

5.2. Simulated Dye Study Results – As mentioned in section 4.2.6 above, the calibration of the model based on measured dye concentrations was very challenging due to comparing different units (RFU and ppb) without a conversion factor and picking up "background" fluorescence in the river. Additionally, the dye study measurements at the intake were inconclusive since no definitive amount of dye was measured at the intake. Figure 10 shows the dye concentrations at the GCWW intake for day 2 of the dye study, further presentation of GCWW dye study results can be found in Appendix A. A quick spike in concentration was observed around 11:02 A.M., before the plume arrived at the intake, which was not expected to occur until after 11:30 A.M. No other dye concentration spikes at the intake were observed throughout the experiment.

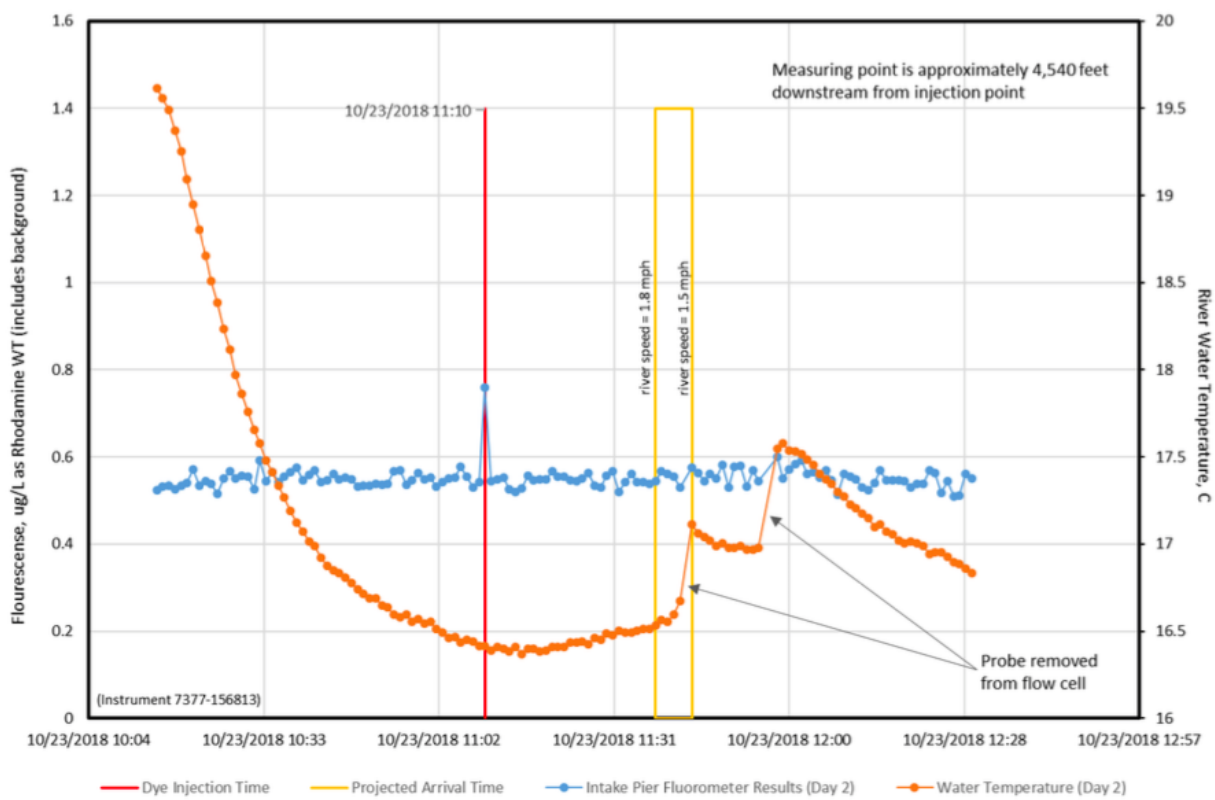

Figure 10. Fluorometer results at the intake pier on day 2 of the dye study

Figure 11 below displays an aerial view of the simulated dye plume at the intake compared to an aerial shot of the dye plume from day 2 of the dye study at the intake, representing that the model reproduced similar results to those that were visually observed.

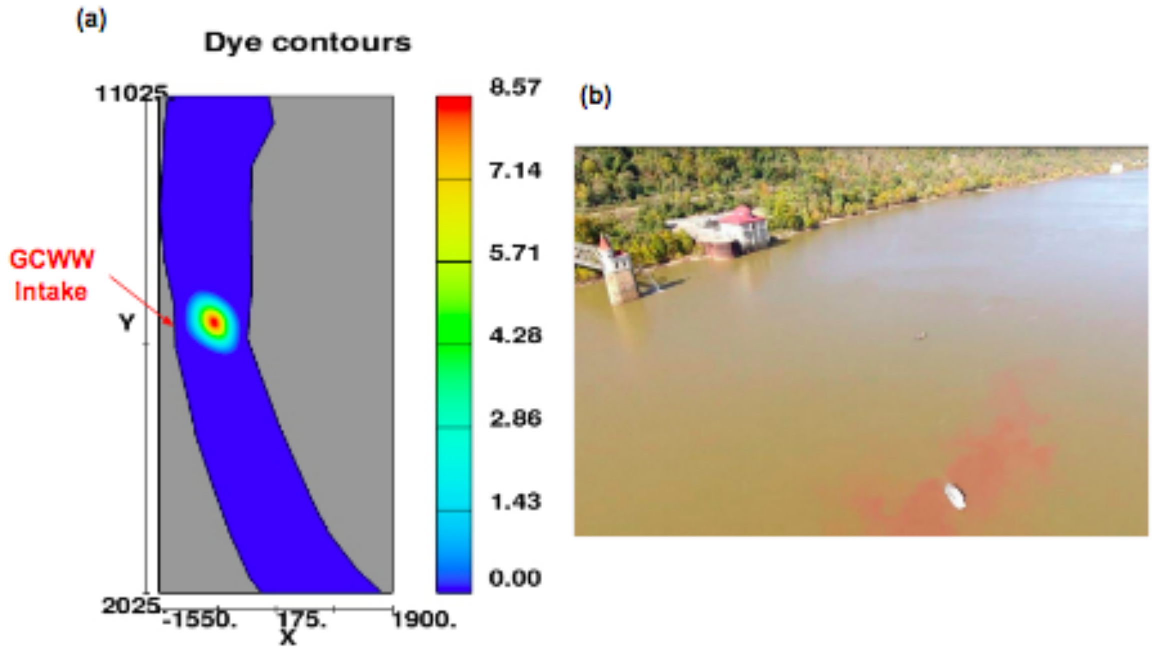

Figure 11. ***(a)*** **The simulated contaminant plume at the intake compare to** ***(b)*** **the dye plume on day 2 of the dye study at the intake**

5.3. Simulated Flow Results – The 90th percentile flow (200,000 cfs), median flow (91,900 cfs), and 10th percentile flow (30,000 cfs) were also simulated. In these simulations the dye entered the river 700 ft from the Ohio side along the Combs-Hehl bridge. The 90th percentile flow was found to have the smallest amount of lateral dispersion, and a scalar concentration 0.054 ppb at the GCWW intake. The median flow had an average amount of dispersion with a scalar concentration of 0.19 ppb at the GCWW intake. The 10th percentile flow was found to have the largest amount of lateral dispersion with a scalar concentration of 1.26 ppb at the GCWW intake. The slower the flow rate of the river, the more lateral dispersion takes place which causes higher concentrations of the scalar to be simulated at the GCWW intake. Figure 12 below shows the dye contours in the transects of the river at the GCWW intake under the three flow conditions under study.

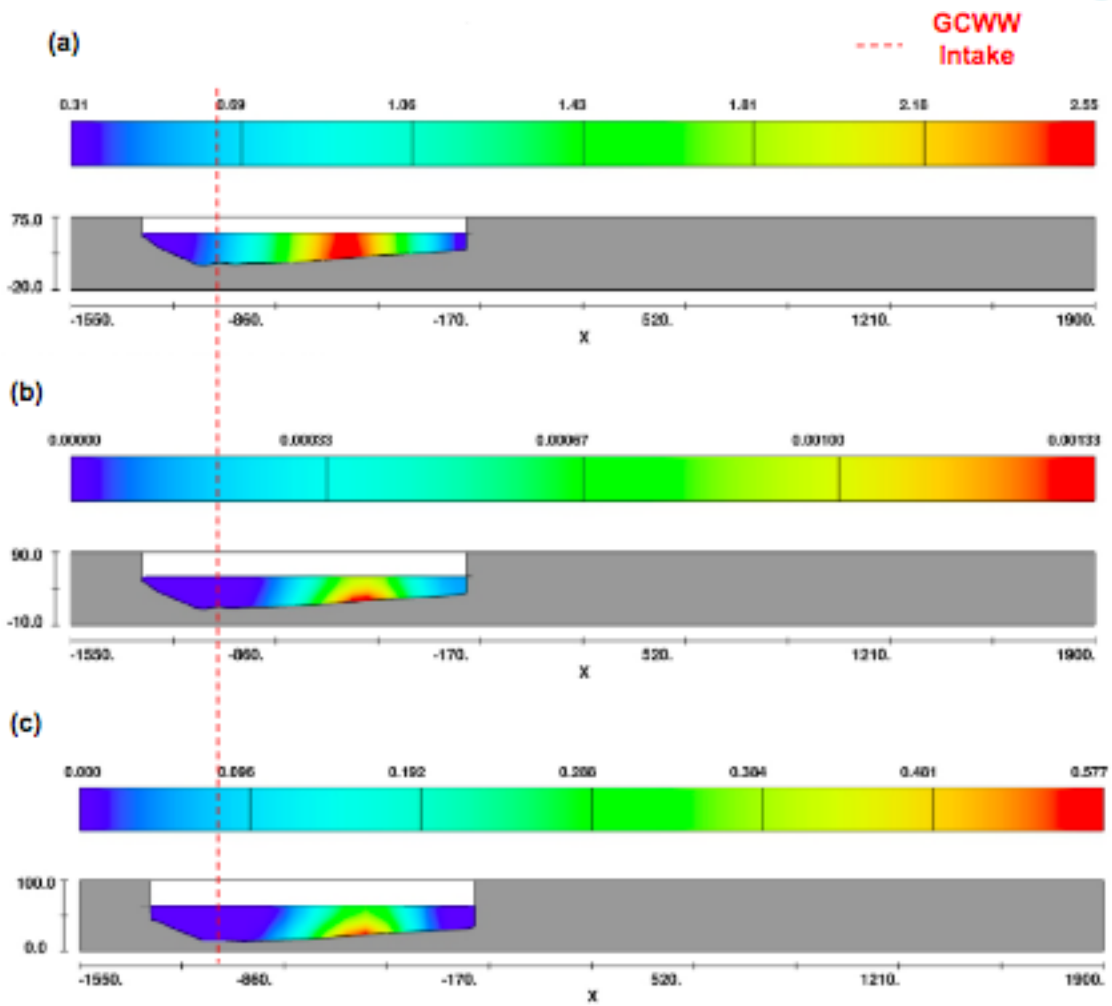

Figure 12. Dye contours in ppb at the GCWW intake for volumetric flow rates of *(a)* 10th percentile flow conditions *(b)* median flow conditions *(c)* 90th percentile flow conditions

5.4. Bridge Downspout Locations – Testing locations needed to be assigned along the Combs-Hehl bridge in order to determine which downspout location would provide minimal risk to the GCWW intake from a pollutant spill. Precision point determined the midpoint of the bridge at the middle pier to be the starting position for the first test location. A line was drawn in Rhino 3D from the middle pier to the pier on the Ohio side of the river. This line was divided into 16 segments to have 15 evenly dispersed points separated by 40 ft. The model was run for each of these bridge locations under each flow condition specified in section 5.1 of this report. Geographic coordinates of each bridge location 1-15 was inputted as the mass momentum source location of the scalar that represented either the dye in the case of simulating the dye study, or the pollutant in the cases of a hypothetical spill. Figure 9 below displays the 15 test locations of a spill discharge in the Ohio River.

Figure 9: Downspout locations 1-15 along Combs-Hehl Bridge

5.5. Results of Various Bridge Locations and Pollutant Concentrations – Flow-3D was run a total of 45 times in order to simulate the effects that each of the fifteen bridge locations had on the concentration of the pollutant at the GCWW intake under each of the three flow conditions under study, where the initial pollutant concentration was an extremely concentrated 1 billion ppb. Table 2 shows the concentrations in ppb of the pollutant at the intake when the pollutant enters the system at each of the fifteen bridge locations under each of the three flow conditions.

Table 3: *Pollutant concentrations in ppb at the intake per bridge location and flow condition*

	Flow rate: 30,000 cfs		Flow rate: 91,900 cfs		Flow rate: 200,000 cfs	
Bridge location No.	Time (min)	Concentration (ppb)	Time (min)	Concentration (ppb)	Time (min)	Concentration (ppb)
1	84.75	853,177.25	35.50	41,039.98	23.08	17,571.01
2	84.75	853,177.25	35.33	41,039.98	23.08	3,096.09
3	84.67	544,706.56	36.17	6,469.67	22.92	1,099.12
4	85.42	397,807.59	36.83	1,384.76	23.00	109.82
5	85.42	223,238.95	37.08	97.93	22.83	36.43
6	86.17	149,070.48	37.58	17.89	23.00	3.18
7	86.08	69,318.80	37.33	5.44	23.00	0.08
8	86.83	41,010.14	37.67	0.86	23.00	0.08
9	86.83	15,203.00	38.00	0.13	23.08	0.01
10	86.83	15,203.00	38.08	0.01	22.83	0.00
11	87.58	7,809.40	38.33	0.00	22.83	0.00
12	86.92	4,726.11	38.00	0.00	22.75	0.00
13	87.75	2,145.72	38.17	0.00	22.75	0.00
14	88.33	465.19	37.75	0.00	22.50	0.00
15	89.17	280.68	37.42	0.00	22.50	0.00

Figure 13 provides a concentration profile at the intake against the bridge locations for each flow conditions and the time at which the peak concentration for each bridge location reached the intake. The trend lines for each flow condition show an exponential relationship. In each case the concentrations at the intake decrease as the pollutant enters the system closer to the Ohio side of the river.

The 10th percentile flow rate showed the highest concentrations at the GCWW intake. The concentrations were above 100 ppb at all bridge locations, however, the bridge locations closest to the midpoint (bridge location no.1) measured the highest concentration of 853,177 ppb. The concentrations at each bridge location are so high that any point of discharge of the pollutant along the bridge will be pulled into the intake, so these flow conditions will not be used to design the optimal bridge downspout location. Under low flow conditions the time it takes the plume to reach the intake from these bridge locations varies from about 85 minutes to 89 minutes. Although the 10th percentile flow allows pollutants to reach the intake no matter at which discharge point, it also allows the most response time before the peak concentration of the plume reaches the intake when compared to the the other two flow conditions simulated.

Median flow conditions showed significantly less concentrations of the pollutant at each point along the bridge than the low flow conditions. Pollutant concentration at the intake reaches around 1 ppb at bridge location 8. A maximum concentration at the median flow rate was 41,040 ppb. The plume took between 35.5 minutes to 38 minutes under these flow conditions to reach the intake.

The 90th percentile flow displayed the lowest concentrations of pollutant at the GCWW intake, with the maximum concentration reaching 17,571 ppb. Pollutant concentrations reached below 1 ppb at the intake by bridge location 7. The river at this condition is moving fast enough to carry the plume past the intakes without too much lateral dispersion taking place. The least amount of time and the least variance of time for the peak plume concentration to reach the intake was observed under the 90th percentile flow conditions at 22.5 minutes and 23 minutes.

These model results show that the lower flow conditions prevent a higher risk for lateral dispersion of a pollutant to reach the GCWW intakes. Since the median flow conditions (91,900 cfs) was the lowest flow tested that showed concentrations below 1 ppb, this was the flow rate selected to design the optimal bridge downspout location. The low flow conditions (30,000 cfs) did not get below this 1 ppb threshold at the intakes and represents a scenario where other preventative measures must be in place since the bridge discharge location alone will not prevent pollutants from reaching the intake. As mentioned above, under median flow conditions, location 8 is the first bridge location to yield pollutant concentrations at the intake under 1 ppb. So, as a factor of safety, Precision Point conservatively recommends bridge location no. 9, located 327 ft from the Ohio side bridge pier, for optimal downspout discharge. A pollutant discharge of 9,000 gallons at 100% purity with a median flow rate would take about 38 minutes for the peak concentration of 0.13 ppb to pass the intakes. Precision Point did not opt to select a bridge location closer to the Ohio side due to the imperfections of the bathymetry data on that shoreline and the limitations of the model to accurately simulate at which bridge location any pollutant pooling may occur along the Ohio side. At bridge location 9, Precision Point is confident that the pollutant discharged at bridge location 9 would not be reach the GCWW intakes.

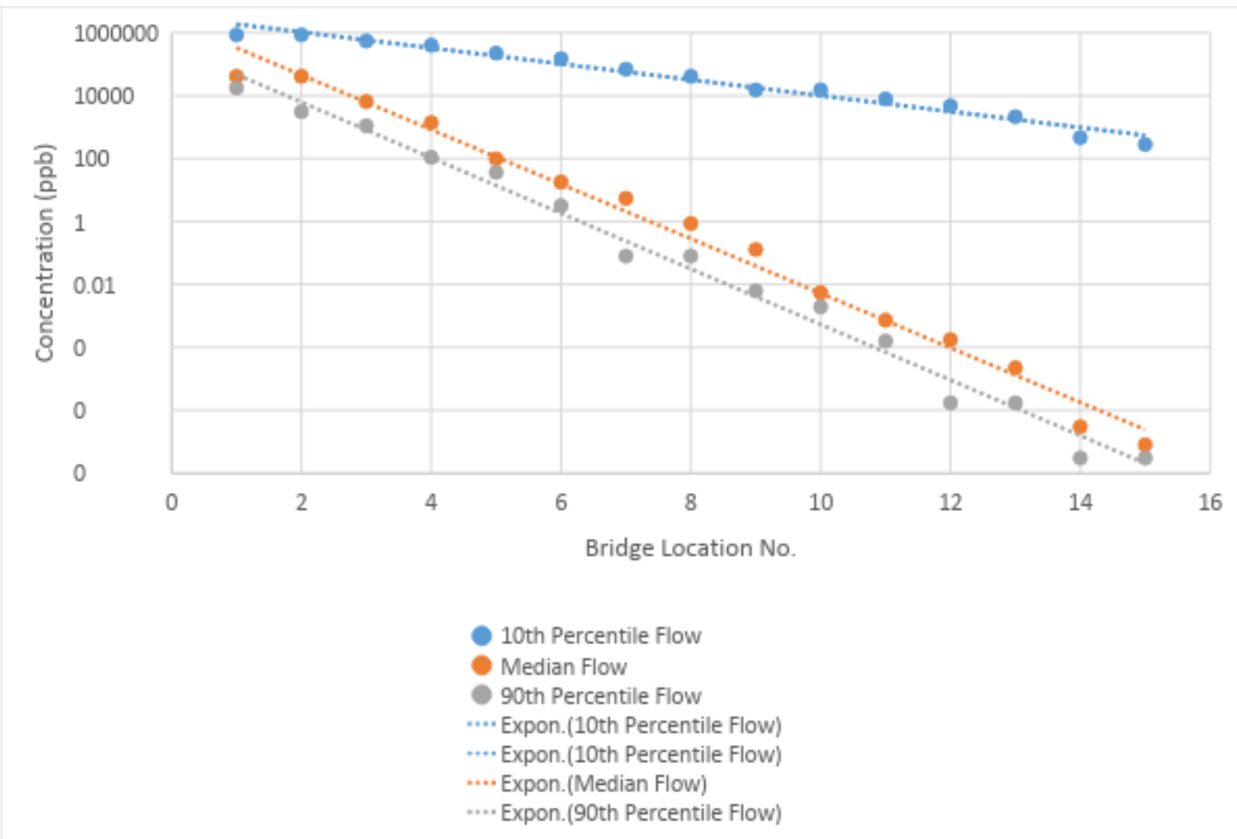

Figure 13. Dye concentrations at the intake for the three flow conditions under study at the fifteen bridge locations

6. Conclusion

6.1. Model Performance – Flow-3D was an extremely useful and successful model in order to achieve the goals of this project, determining an optimal bridge downspout location to prevent pollutants reaching the GCWW intake. The selection criteria of professional guidance and tutorial availability proved to be critical aspects of using the model. Precision Point was challenged to learn a completely new software, which would not have been possible without the help of Flow-3D experts to advise us on which model parameters would be necessary to complete the scope of the project. The interactive GUI in Flow-3D facilitated our use of the model, simplified the model setup, and improved workflow. The post-processing capabilities of Flow-3D were also extremely adept in creating customizable output. Flow-3D generated intuitive figures such as transects and aerial views of the contaminant dispersion throughout the river reach. Hydraulic data and scalar data could also easily be exported into Excel files in order to render different visual analysis of the calculations completed in the model.

6.2. Model Results – The recommend model, Flow-3D, performed simulations of contaminant transport in the Ohio River between the Combs-Hehl bridge and the GCWW water intakes. The model was calibrated to the dye concentrations measured from the dye study with a correlation coefficient, r, of 0.65. Simulations of the model were repeated under three different flow conditions, the 10th percentile flow at 30,000 cfs, the 90th percentile flow at 200,000 cfs, as well as the median flow at 91,900 cfs. In addition, simulations of fifteen evenly spaced discharge points along the Combs-Hehl bridge were conducted. The contaminant was modeled to represent a tanker truck spill of 9,000 gallons.

The results of comparing the simulation at each bridge location under each flow conditions showed that under 10th percentile flow, there is no bridge location that will prevent a contaminant of a tanker truck volume from reaching the intake. However, the spill under 10th percentile flow conditions took 85-90 minutes to travel to the intake, which could be adequate time for GCWW, and NKWD to take preventative measures to protect the water treatment plants if emergency response procedures are effectively in place.

Under the median flow conditions, on average the contaminant plume reached the intake in 37.3 minutes. This is a much smaller window for GCWW and local bodies of emergency response to take action. But, at bridge location 9, 327 ft from the Ohio side, there is no uptake of the pollutant at the GCWW intake. This optimal bridge location allows the contaminant plume to flow past the intakes.

High flow conditions such as the 90th percentile flow presented the lowest risk of the pollutant having enough time to laterally disperse and reach the intake. The plume under these conditions takes an average time of 23 minutes to reach the intake, which is by far the least amount of time to respond to a spill.

Precision Point recommends to use the median flow conditions in selecting the optimal discharge point since the lower flows have more risk of the pollutant dispersing laterally and reaching the intake. This can be seen in the lowest flow conditions (30,000 cfs) where no bridge location will prevent the pollutant from reaching the intake. Applying the optimal bridge location number 9 provides a conservative approach since under median flow conditions (91,900 cfs), the pollutant concentration from bridge discharge location number 8 is under 1 ppb. Moving one bridge discharge location further from number 8 provides a factor of safety for some variances in river flow conditions.

Most importantly, the sponsors of this project should heavily consider and weigh in the impacts that the U.S. Army Corps of Engineers locks and dams have on the Ohio River and its flow conditions. In 2015, an algal bloom caused by extremely low flows generated from the locks and dams control greatly impacted the river reach under study in this project. The water treatment plants were able to maintain operations through this time, but they were forced to adjust their procedures to account for the different type of toxins they were pulling in during this time. These extremely low flows, lower than 30,000 cfs, will have similar if not increased affects seen by the model under 10th percentile flow conditions. No positioning along the bridge changed the fact that adequate lateral dispersion could occur and therefore allow the contaminate to reach the intake. This would only be exacerbated by even lower flows induced by the locks and dams and would represent the highest rick flow conditions that could affect this study area relative to a spill from the Combs-Hehl bridge.

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8. Acknowledgements

Precision Point would like to honor and thank the following teams and individuals for their contributions to the completion of this project:

- Dr. Drew McAvoy for his guidance, advice, and connection with expert Flow-3D programmer
- John Richardson and Randy Lagumbay for their professional guidance about Flow-3D modeling
- The dye study project team; Richard Stuck, the members of Greater Cincinnati Water Works, Northern Kentucky Water District and Ohio River Valley Sanitation Commission for their teamwork, knowledge, equipment, and successful execution of the dye test
- Victoria Bauscher for designing and developing Precision Point's logo.

9. Appendices

9.1. Appendix A: Dye Study Pictures and GCWW Summary Presentation

Figure A-1: Day 1 Injection

Figure A-2: Day 1 Intake

Figure A-3: Day 2 Plume

Figure A-4: Day 1 Halfway to the intake

Figure A-5: Plume

Figure A-6: Day 1 Boat 1 equipment to collect water samples.

Figure A-7: Dye (left) equipment to collect water samples (right)

Figure A-8: Day 1 Plume as seen from Boat 1

Figure 4. Example of Previous Ohio River Dye Study

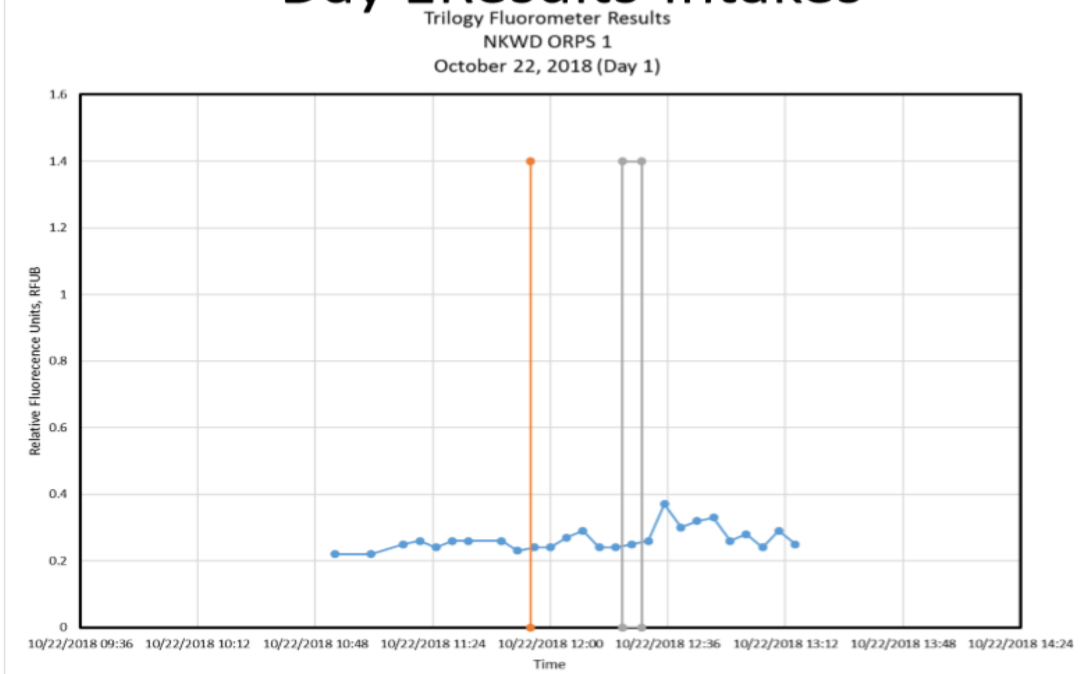
Figure 5. GCWW Intake (foreground) and NKWD Intake (background)

Day 1: Injection

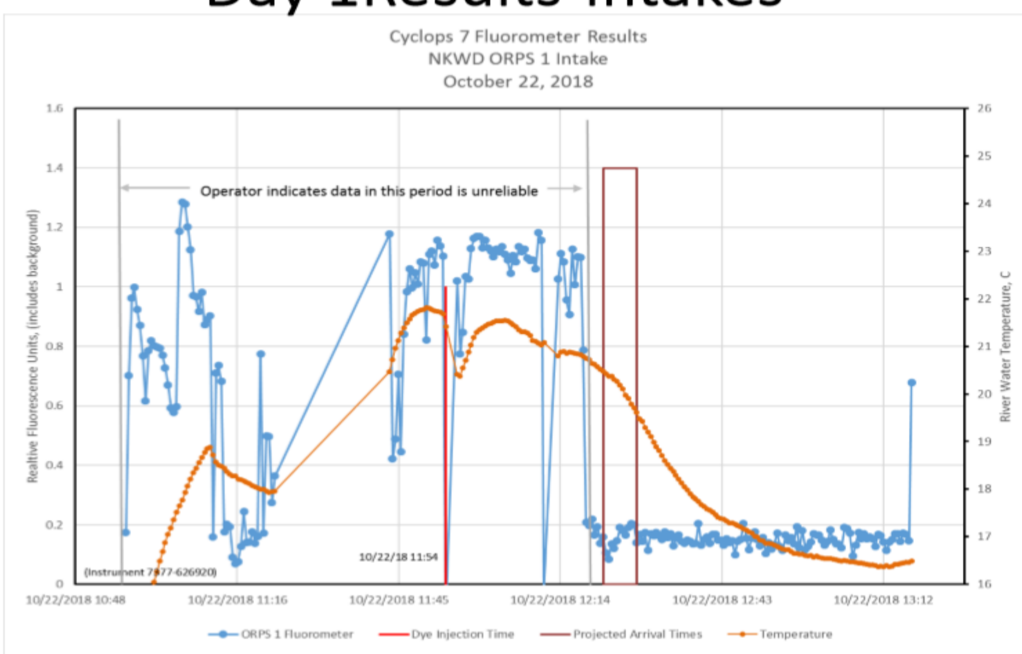
Day 1: Halfway to Intake

Day 1: Parallel to Intake

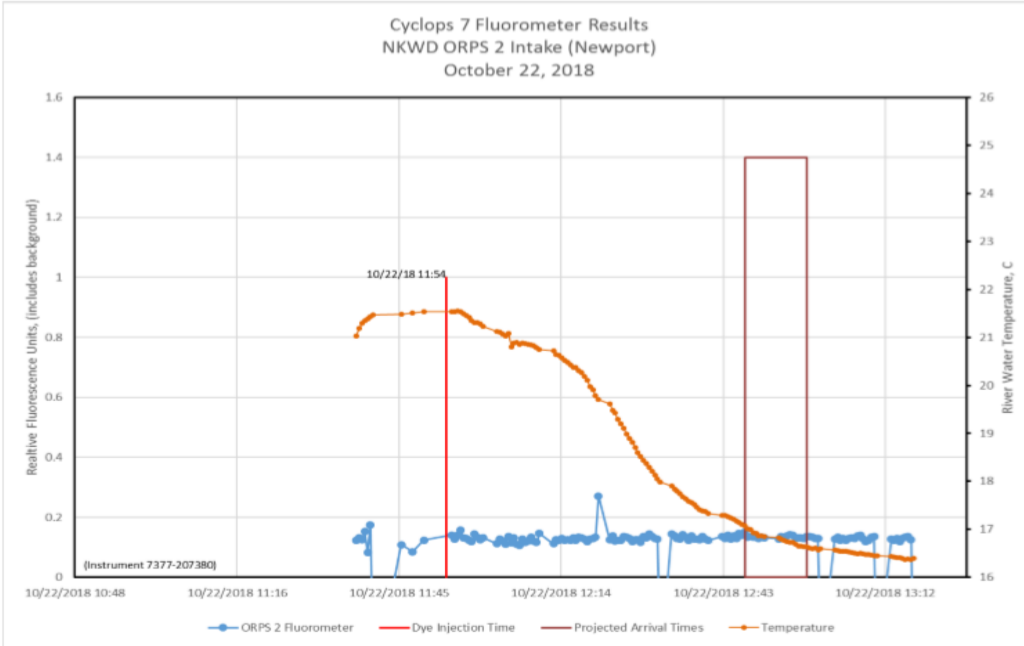
Day 1Results-Intakes



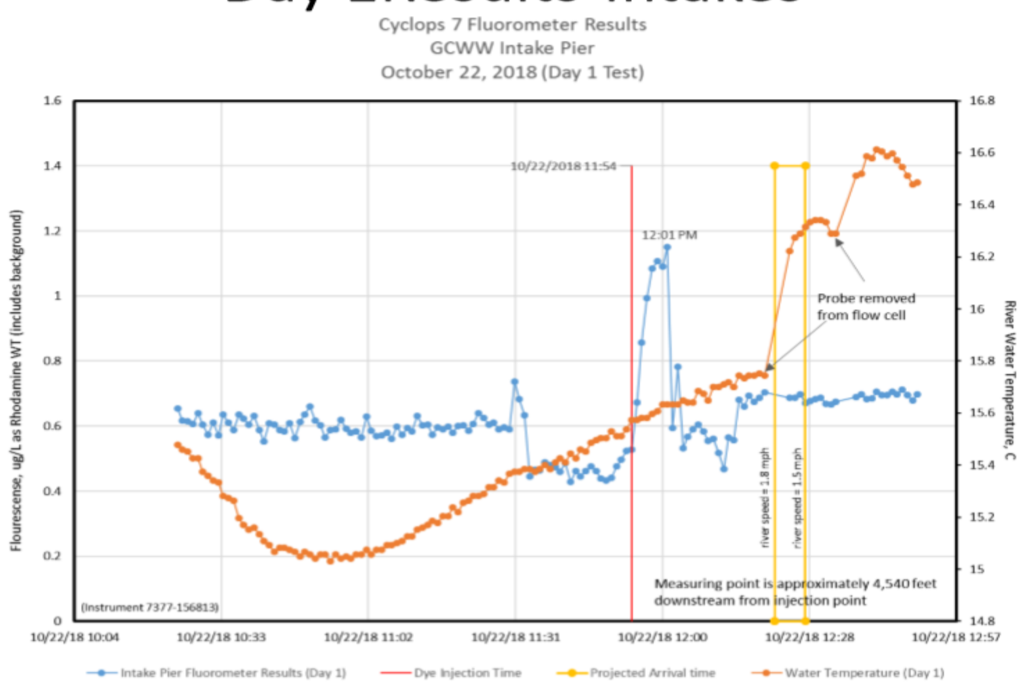
Day 1Results-Intakes



Day 1Results-Intakes



Day 1Results-Intakes



Day 1 Issues & Observations

- Transects data set didn't work out, not really sure what happened.
- Plume was a bit too short, it would have been helpful to have a slightly longer plume.
- Plume stayed fairly close to the Ohio side

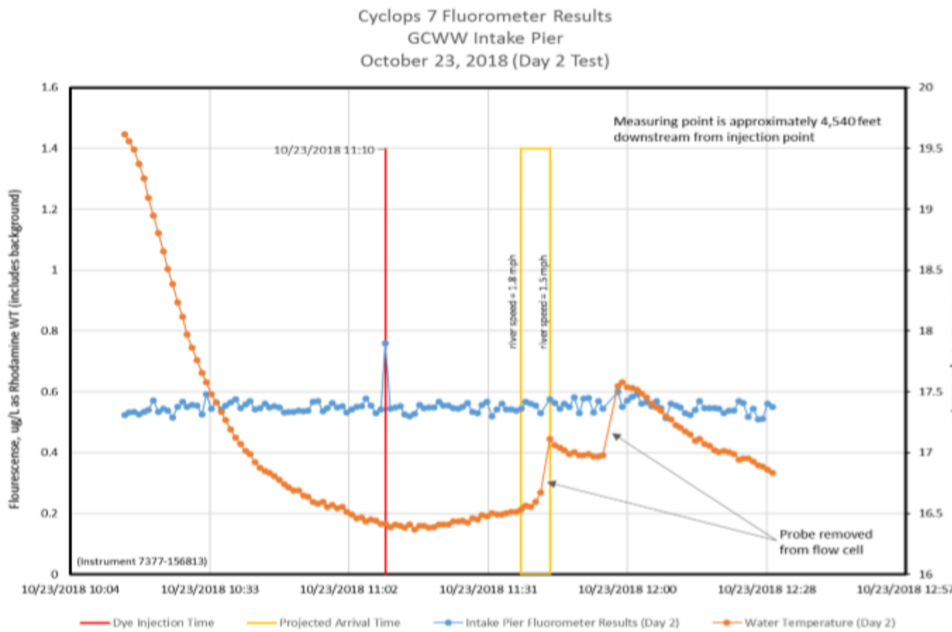
Day 2

- Day 2: Released dye approximately 700 ft from the Ohio bank, measured for dye at 4 intake locations and 15 transects across the plume as it migrated downstream.
- Increased the dye amount to 2 liters with a 90 second injection.

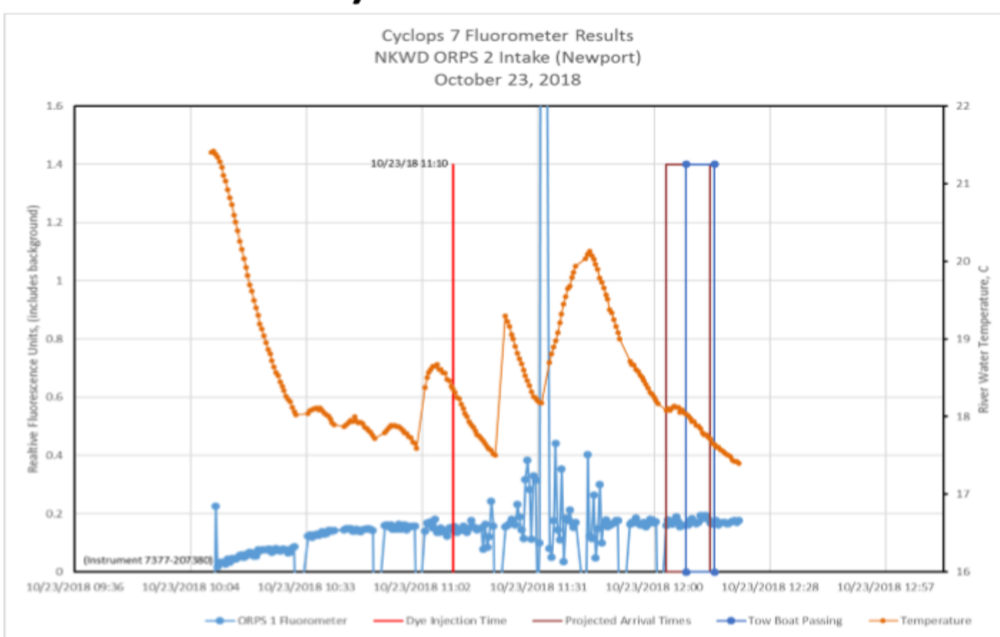
Day 2: Dye Tracing Transects

Day 2: Injection

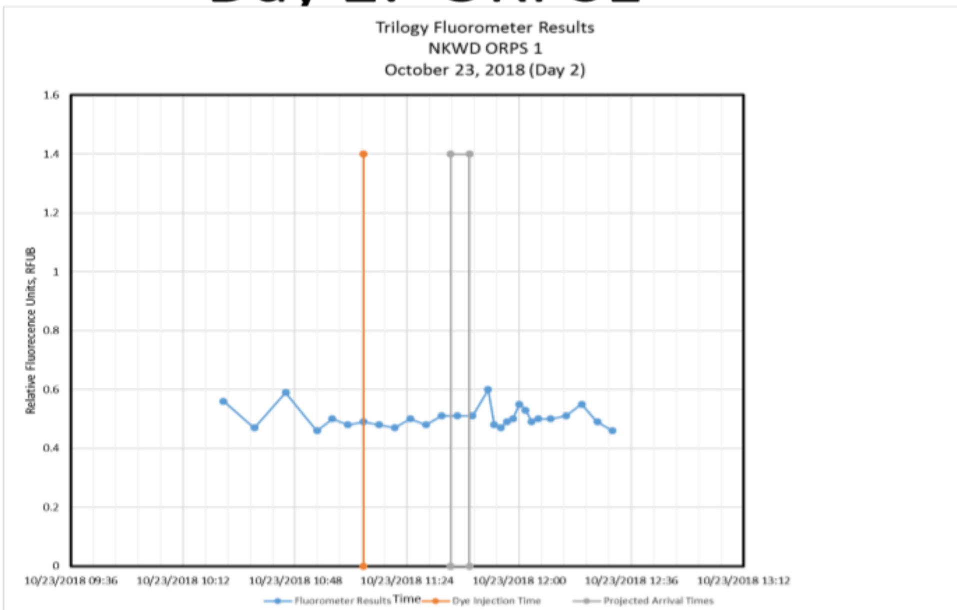
Day 2: Intakes



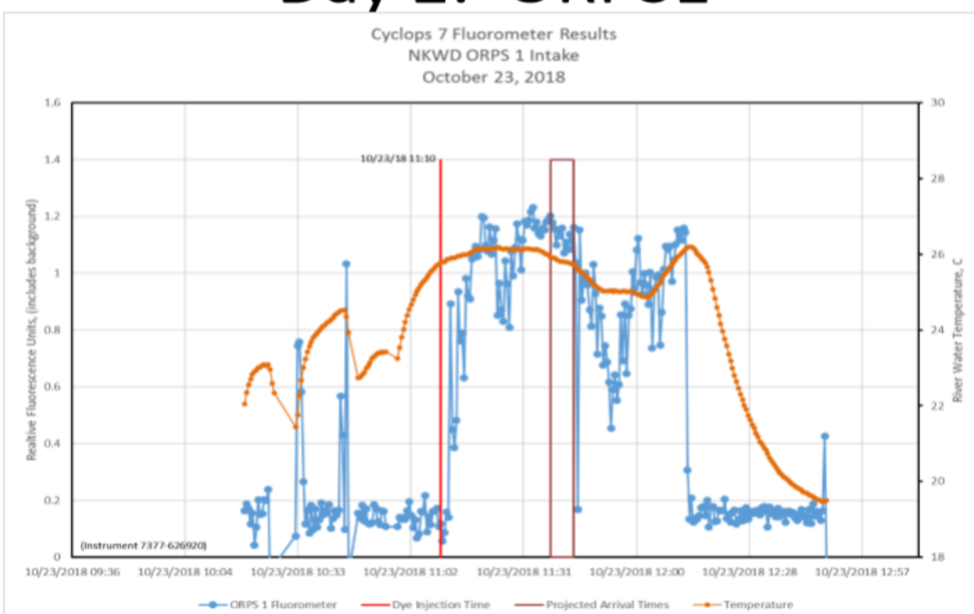
Day 2: Intakes



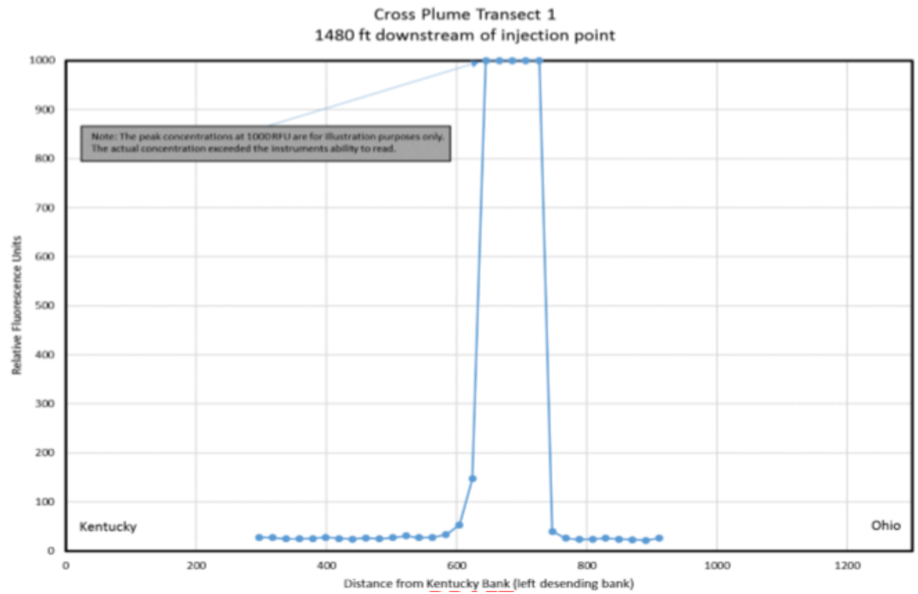
Day 2: ORPS1



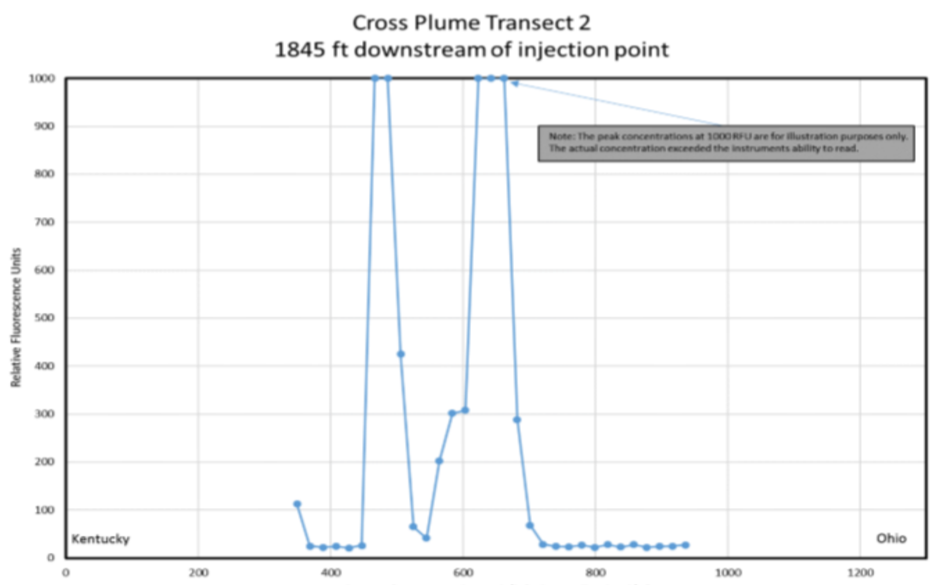
Day 2: ORPS1



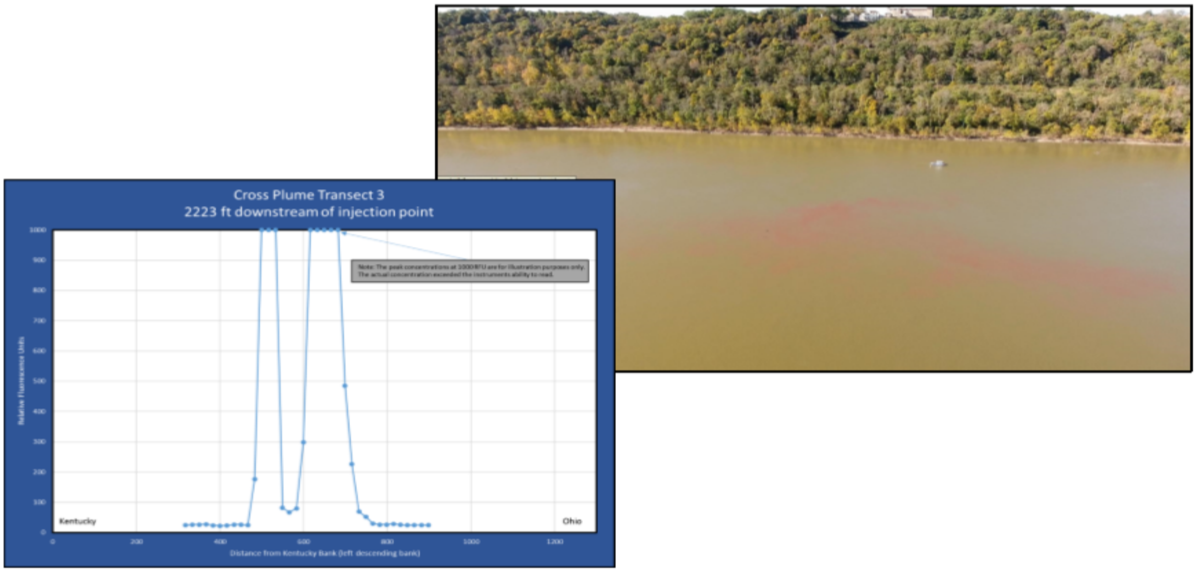
Day 2: Transects 1 & 2



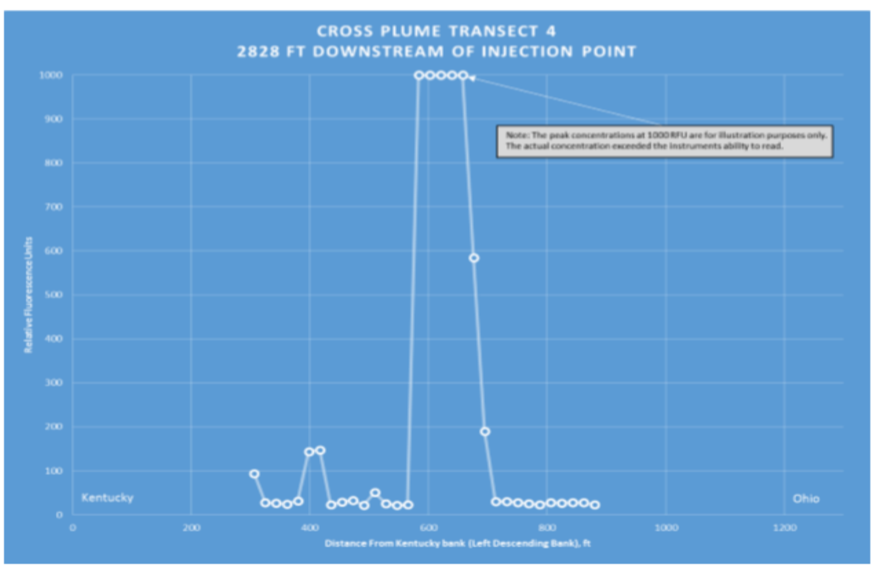
Day 2: Transects 1 & 2



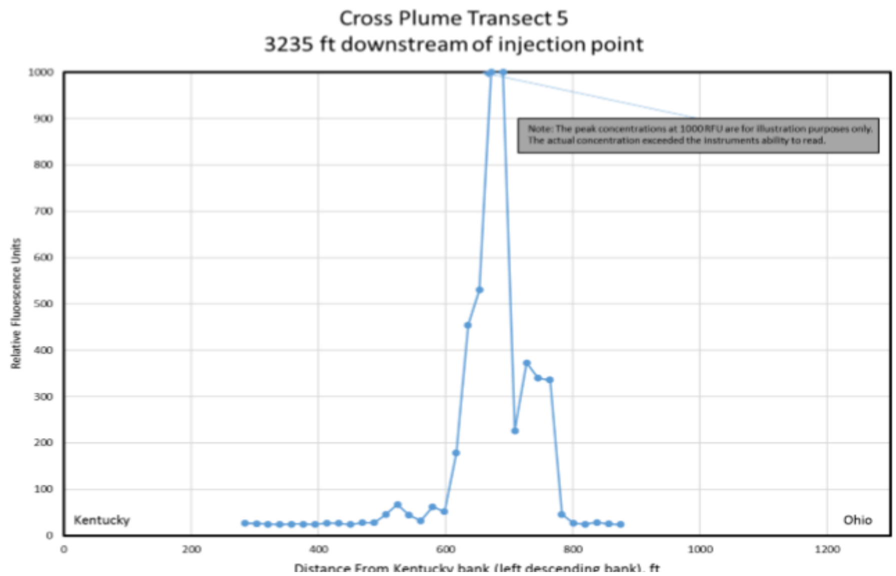
Day 2: Half Way to Intake



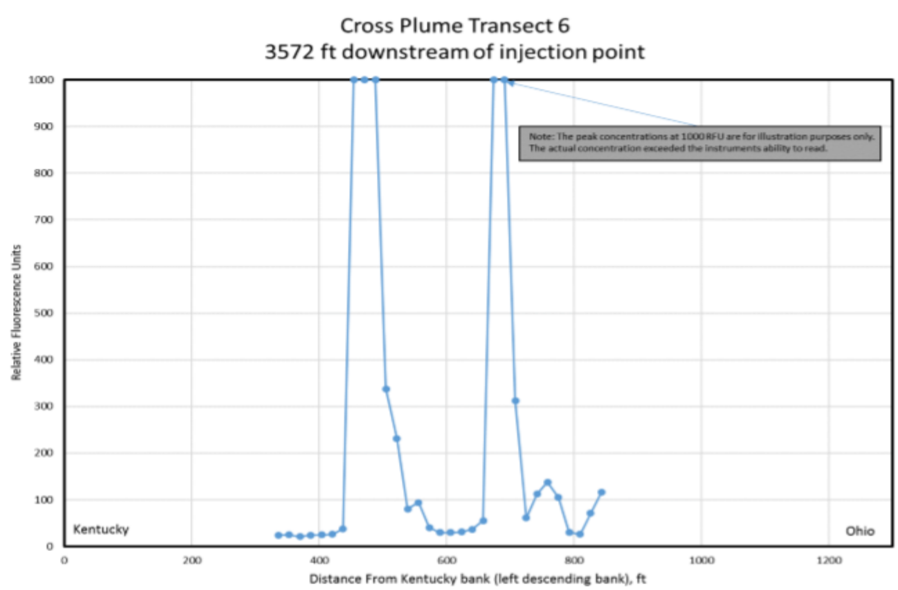
Day 2: Transects 4 & 5



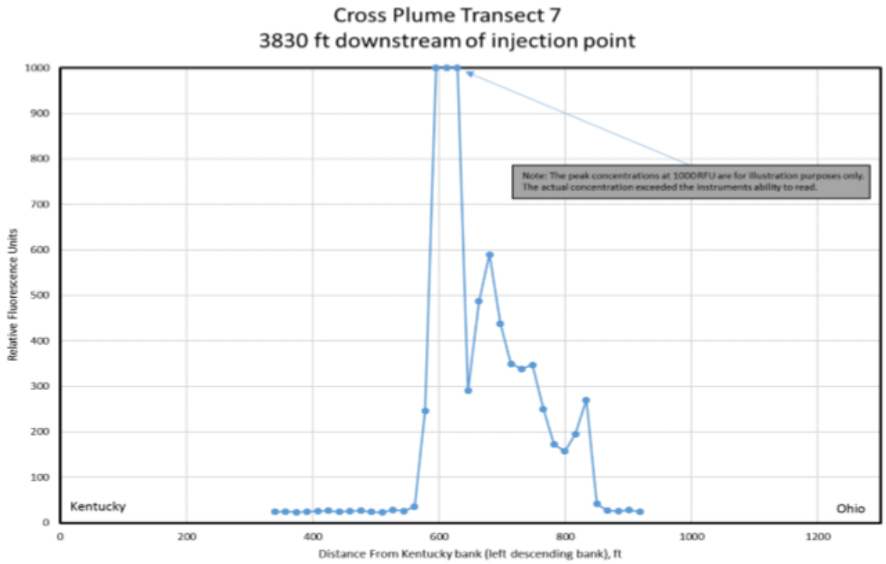
Day 2: Transects 4 & 5



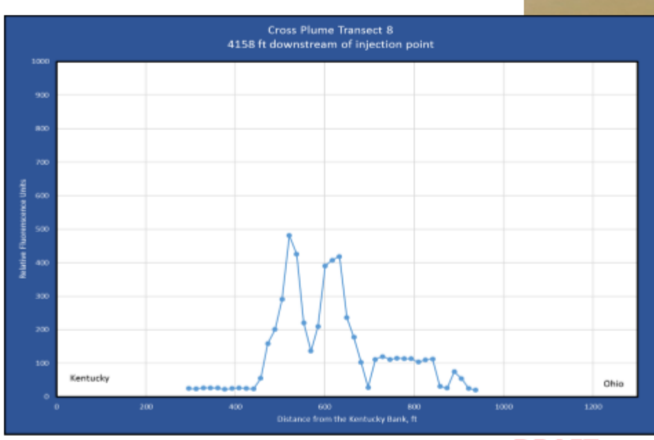
Day 2: Transects 6 & 7



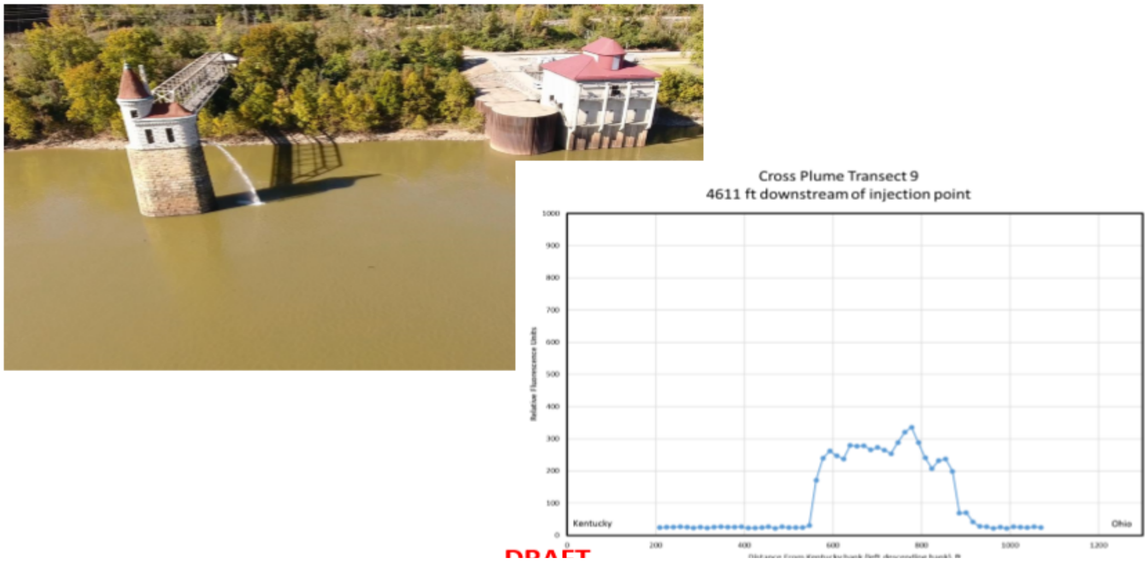
Day 2: Transects 6 & 7



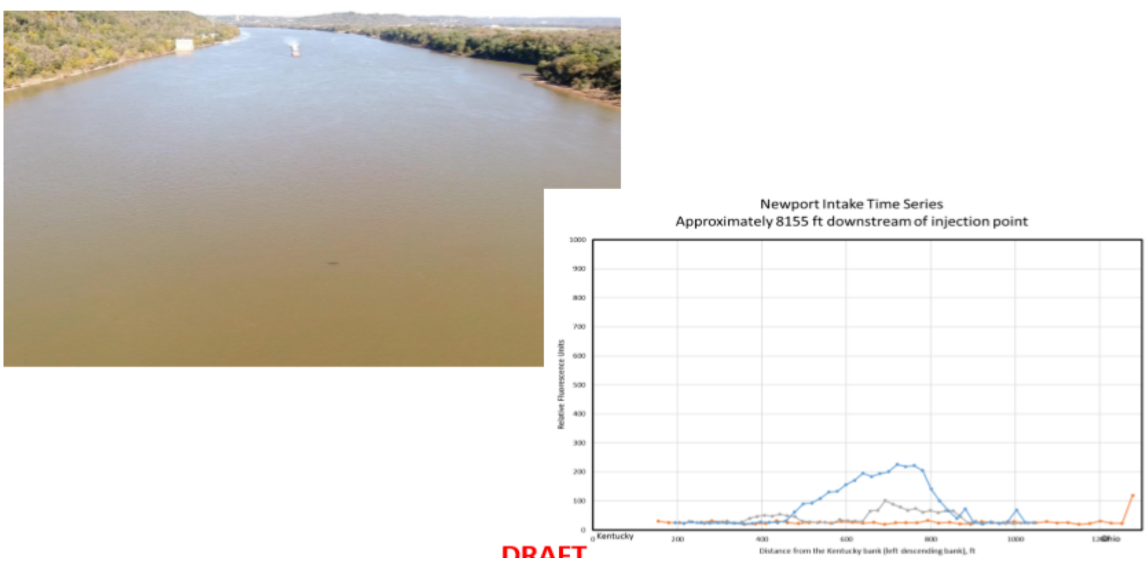
Day 2: Parallel to GCWW Intake



Transect 9-Between the Intakes



Transects 12, 13 and 14



PRECISION POINT

Plume Outline

Preliminary Observations

- Dye was not detected at the GCWW or NKWD Ft Thomas Intake on either day
- Dye may have been detected at low concentrations at Newport intake on Day 2.
- Dye was not observed reaching either bank within the study reach.
- Maximum measured plume width was 472 ft wide
- Plume edges became more gradational after approximately 5000 ft

9.2. Appendix B: 3D Model Outputs

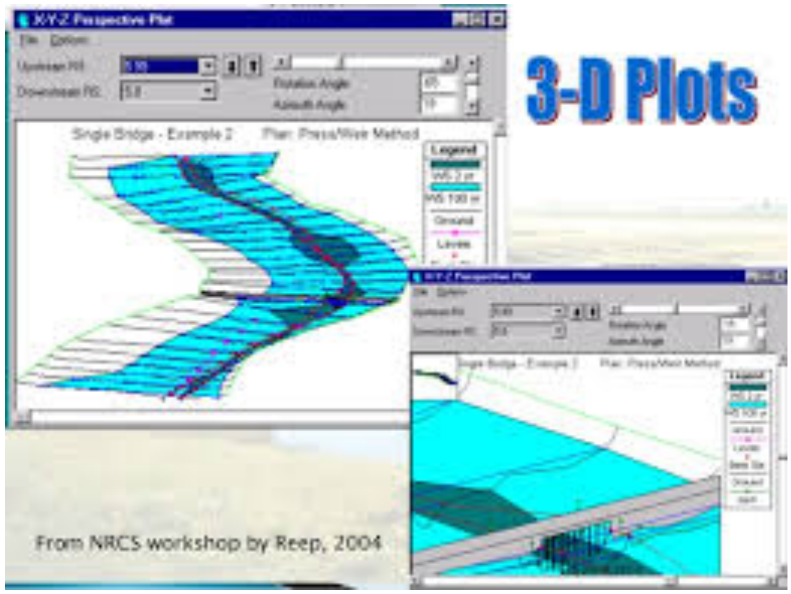


Figure B-1: HEC-RAS sample output

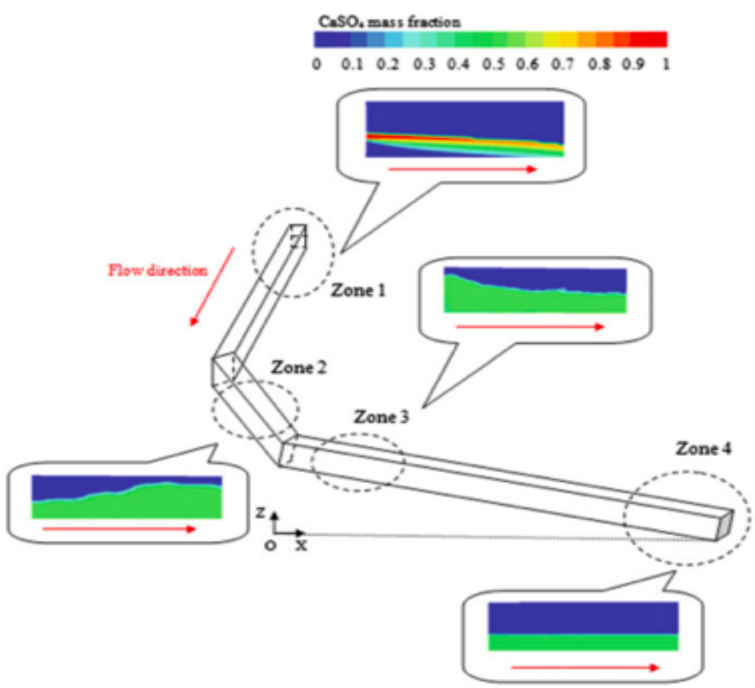


Fig. 4 Pollutant concentration for a cross-section in the median plane of the sewer

Figure B-2: ANSYS Fluent output modeling wastewater discharge into a sewer system

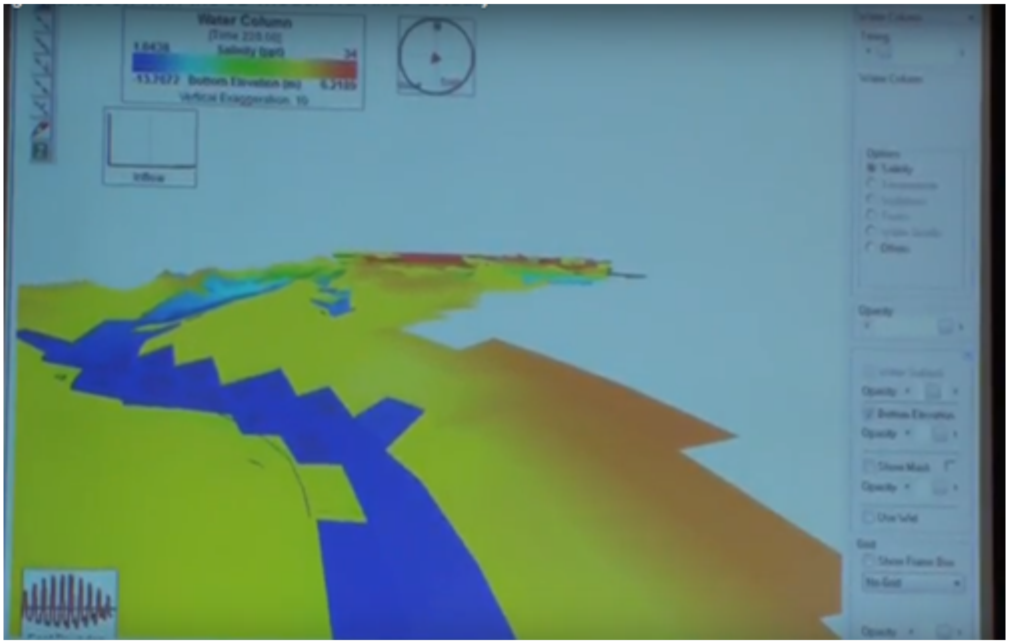


Figure B-3: EFDC output modeling short stretch of a river

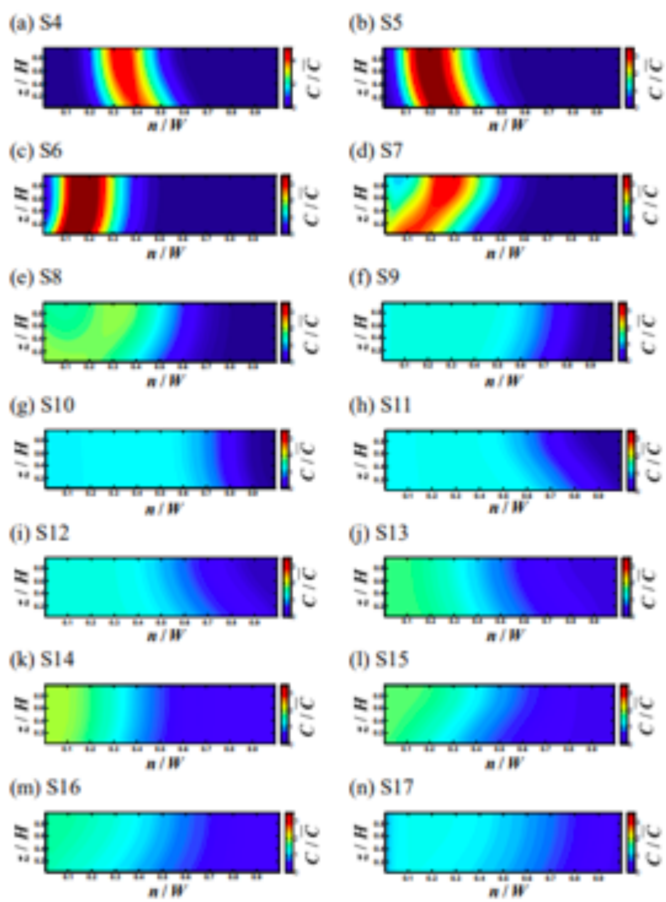


Figure 5.23.3 The cross-sectional concentration distributions for SN190.

Figure B-4: OpenFOAM output of 3D numerical simulation of hydrodynamics and pollutant transport in meandering channels

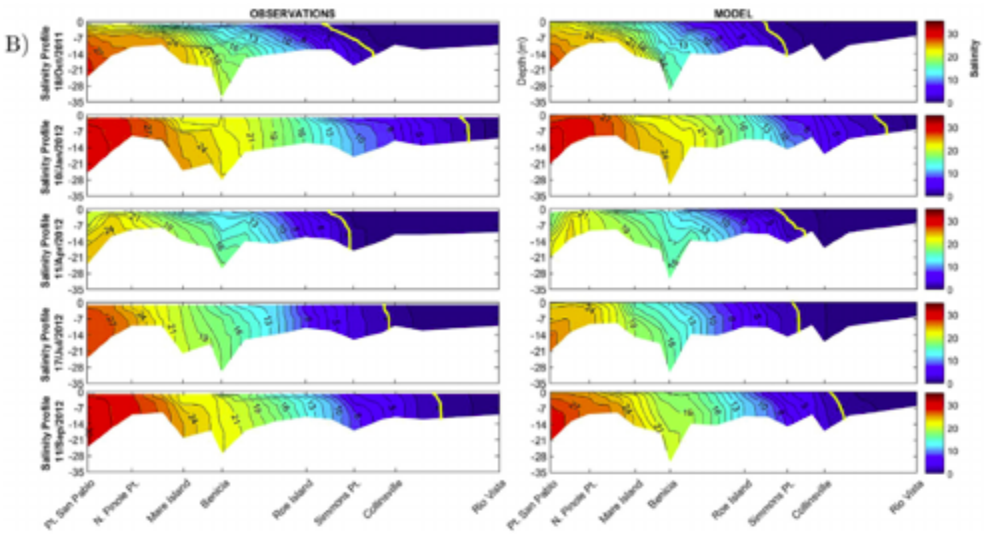


Fig. 7. Observed (left panel) and modeled (right panel) salinity longitudinal profiles in San Francisco North Bay during WY2011 (A) and WY2012 (B). The Pacific Ocean is oriented to the left, and upstream toward the Sacramento River to the right, of each figure. The 2 isohaline is shown in a thick yellow line. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Figure B-5: Delft3D output of numerical model of flows and salinity dynamics in the San Francisco Bay-Delta

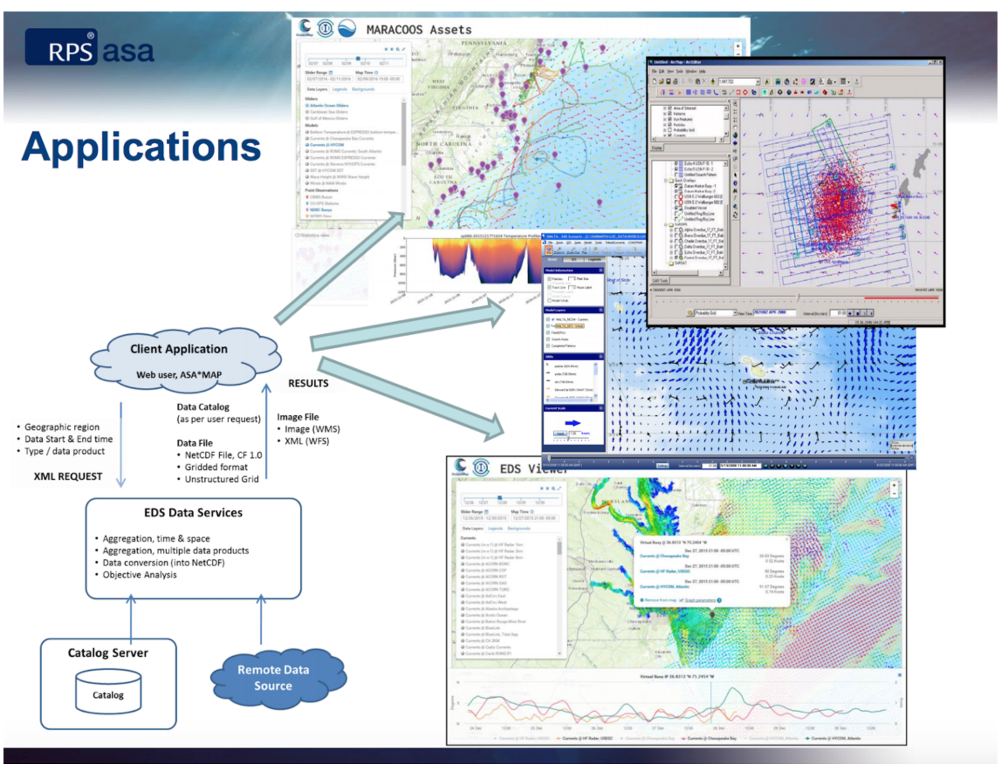


Figure B-7: CHEMMAP applications and examples of output

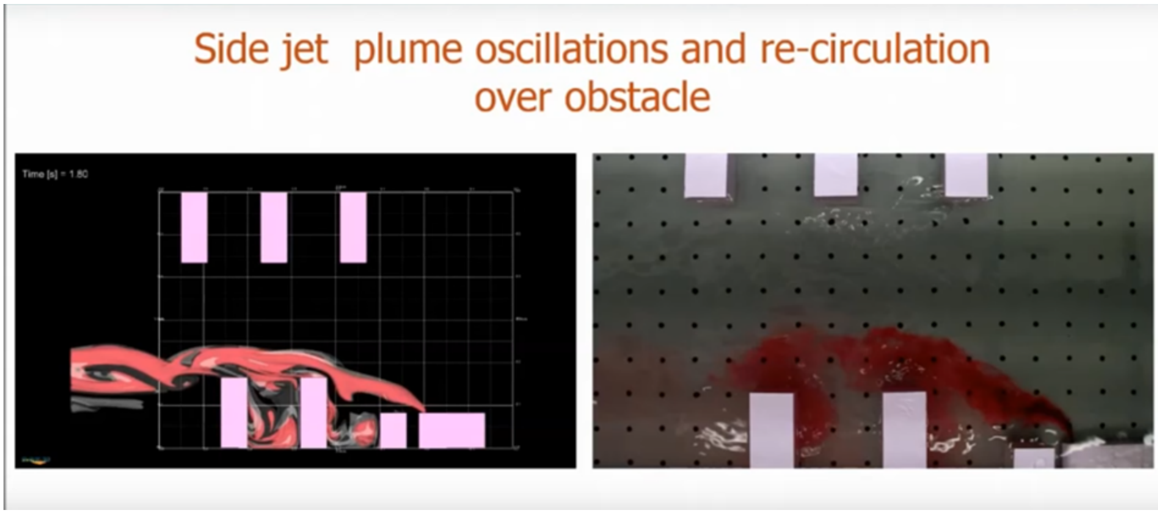


Figure B-8: Flow 3D modeling capabilities computing a dye simulation

9.3. Appendix C: Alternative Analysis Tables

Table C-1: Weighted alternative analysis of the top three models

Criteria	Weighting	Flow 3D	OpenFOAM	ANSYS Fluent
Visualization of Results	5	3 (15)	2 (10)	3 (15)
3D Capability	7	3 (21)	2 (14)	3 (21)
Professional Guidance	6	3 (18)	1 (6)	2 (12)
Cost	4	2 (8)	3 (12)	1 (4)
Availability of Tutorials	2	2 (4)	2 (4)	2 (4)
Ease of Use	3	3 (9)	1 (3)	2 (6)
Pre / Post Processing Intensiveness	1	3 (3)	2 (2)	2 (2)
Pre-weighted score		19	13	15
Max Pre-Weighted Score	21			
Weighted Score		78	51	64
Max Weighted Score	84			

9.4. Appendix E: Vision Statements and Engineer Bios

9.4.1 Company

Precision Point

9.4.2 Vision Statement

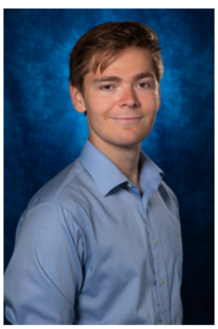
Providing optimal computational analysis solutions in source protection to mitigate risk and prevent disaster.

9.4.3 Engineer Bios

Bethany Caspersz – Surface Water Modeling Management Specialist

Bethany Caspersz is a fifth year Environmental Engineering Student at the University of Cincinnati. She has completed 4 semesters of co-op with GE Aviation in the Environmental Health and Safety department at three different manufacturing sites. She also has experience with UC's Water Systems Analysis Research Group under Dr. Patrick Ray.

Matthew Cummings – Project Leader and Model Investigation Coordinator



Matthew Cummings is a fifth year Environmental Engineering student at the University of Cincinnati. His skills and academics have led him to a full-time position at the Kroger Co. as a Refrigeration Designer after completion of his degree. His role will include designing commercial refrigeration systems using AutoCAD for all Kroger stores within the country. He also has previous experience working with Metropolitan Sewer District as a Land Survey Co-op and working as a technician for Environmental and Engineering Services Co. His greatest attributes are my ability to solve problems, communication skills, technical skills in AutoCAD and ArcGIS, work ethic, pragmatic mindset, and creative problem solving. Matthew will be graduating this spring with a bachelor's degree in Environmental Engineering.

Dexter Adams – Task Leader Managing Channel Flow Model Investigation

Dexter Adams is a fifth year Environmental Engineering student at the University of Cincinnati. As well as the academic portion of his education, he did research for the University of Cincinnati which include operating advanced equipment to measure particulate matter in the atmosphere. Another responsibility of this position included programming to analyze the data being collected. This processed data was then put thorough graphical software to create maps indicating areas of high pollution.

Qianhui Xia – Task Leader Managing Channel Flow Model Investigation

Qianhui Xia is a fifth year Environmental Engineering student at the University of Cincinnati. She is able to manipulate technical software MATLAB and ArcGIS. Her excellent skills include problem-solving, team-work and multi-tasking which have helped her with previous work experiences. She has been working at the University of Cincinnati as an air quality researcher, who was responsible for collection of air pollutants concentration and MATLAB analysis of data sets. She also had an experience as a biodiesel researcher and producer at UC about recycling of waste oil. She will be graduating in May 2019 with her Bachelor of Science degree in Environmental Engineering.

9.6. Appendix F: Team Resumes

The following four pages contain the resumes of each member of Precision Point.

Bethany Caspersz

2808 Westonridge Drive | 513-206-0242
Cincinnati, OH 45239 | casperbc@mail.uc.edu

Education & Certifications

University of Cincinnati, Cincinnati, OH
College of Engineering and Applied Science
Bachelor of Science, Environmental Engineering — *Class of 2019*
GPA 3.62/4.0
McMicken College of Arts and Sciences
French Minor — *2019*
Business French Certificate — *2016*

Skills *French, GIS, Matlab, ICP-MS Analysis, RCRA, OSHA Trench Safety, Microsoft Excel, PowerPoint*

Experience

Water Systems Analysis Research Group, University of Cincinnati — *Fall 2018*
Undergraduate Research Assistant
- Implemented 3-D modeling system in Ohio River contamination prevention
- Enhanced efficiency of the team to problem solve, develop and create solutions

GE Aviation, Evendale, OH — *Spring - Summer 2018*
EHS Co-op
- Ensured Hazard Communication compliance by implementing new labeling program
- Managed the site's Stormwater Pollution and Spill Prevention programs and findings
- Executed annual requirements for site's Title V De Minimis air emission sources compliance
- Drove effective partnership of diverse teams through revitalizing EHS Framework Elements
- Coordinated and motivated co-op participation with 400 community service hours as Volunteer Chair of Co-op Committee

GE Aviation, Madisonville, KY — *Summer 2017*
EHS Co-op
- Reduced risk through identifying follow-up actions from Risk Assessments, Incident Investigations, and Ergonomic Assessments using REBA tool
- Tested site's Wastewater Treatment facility by use of ICP-MS Analysis
- Evaluated the site's baseline EHS Culture through a survey of a 524-person workforce
- Coordinated team engagement and community outreach as Co-op Committee President

GE Aviation, Lynn, MA — *Fall 2016*
EHS Co-op
- Developed cross-functional communication by implementing new OSHA compliant lock box procedures for all mechanical presses
- Administered EHS fundamentals training of supervisors for a workforce of 3,000+people
- Achieved goal of 100 service hours as Volunteer Chair of Co-op Committee

The University Club of Cincinnati, Cincinnati, OH — *2013-2018*
Server
- Thrived in fast-paced, dynamic environment by exceeding company and guest needs

Awards & Honors

College of Engineering and Applied Science
- *Dean's List Recipient*, Fall, Spring & Summer Semesters — *2015 – 2017*

McMicken College of Arts and Science
- *Dean's List Recipient*, Fall & Spring Semesters — *2014 – 2017*

Cincinnatus Century Scholarship — *2014 – 2018*

Activities

Society of Women Engineers — *2015 – 2016*
Fundraising Committee

Dexter Adams

2684 Ridgecrest Lane
Covington, KY 41017
859-468-5372
dladam02@gmail.com

Education — **University of Cincinnati, Cincinnati, OH**
Environmental Engineering — **GPA 3.59**

Work Experience

Research Assistant, University of Cincinnati — May (2017) to Present
Collected and processed air quality data
Assembled a personal weather station
Created MATLAB programs relevant to our project

Line Processor, Elovations, Erlanger, KY — July to August (2015)
Validated the contents of packages
Met expectations of 35 packages/hour

Powder Coat Painter, Mazak, Florence, KY — May to August (2014)
Worked as much as 60 hrs a week
Developed powder coating as a skill
Worked in a team of 4

High School

- Salutatorian (2nd in the class academically)
- Team Captain of cross country team
- 100 hours of volunteering for community service

Skills

- Great with programming on MATLAB
- Experience with Microsoft Excel, PowerPoint, and Word
- Very comfortable with computers and electronics
- Some AutoCAD experience
- Python programming

Projects

- Created an interactive GUI in MATLAB capable of projecting elliptical orbits and simulating the launching of a satellite into orbit with explanations of everything involved. It was a collaborative project where I was in charge of modelling the planets in our solar system as well as other notable comets and moons.
- Currently modelling a 3D spill for Greater Cincinnati Water Works to prevent harmful contaminants from reaching their water intake.

MATTHEW CUMMINGS

17 E. University Ave. – Cincinnati, OH 45219
937-638-4601 – cumminmw@mail.uc.edu

EDUCATION

University of Cincinnati, BS in Environmental Engineering, Cincinnati, OH Aug. 2014 – April 2019
- College of Engineering and Applied Science, Class of 2019 (GPA: 3.0/4.0)

Edison Community College, Associates Degree of Science, Piqua, OH Aug. 2012 – May 2014
- 73 Semester Credit Hours Completed, Class of 2014 (GPA: 3.30/4.0)

Anna High School, Anna, OH Aug. 2010 – May 2014
- Advanced College Prep Classes, Class of 2014. (GPA: 3.96/4.0)

WORK EXPERIENCE

The Kroger Co. Jan. 2018 - Current
- Refrigeration Designer working in AutoCAD to remodel Kroger stores throughout America

University of Cincinnati Engineering Library Oct. 2015 –Aug. 2018
- Student librarian handling the front desk of the library.

Metropolitan Sewer District Aug. 2016 – Aug. 2017
- Surveyed over 40 existing and new sewer pipes entering Hamilton Co.
- Learned and gained in experience in the design program, AutoCAD.
- Navigated with ArcGIS to find existing sewers, and using shape files for drawings

EES Group (Environmental and Engineering Services) Dec. 2015 – May 2016
- Worked as an assistant to an Engineer in the field (i.e. measurements, using equipment, etc.)
- Wrote over 20 Forensic Engineering reports, directly sold to insurance companies

Anna Market May 2013 – June 2014
- In charge of inventory stocks, experience in painting, and handling money

Subway Sept. 2012 – May 2013
- Responsible for creating subs, keeping store clean, and operating register

VOLUNTEER EXPERIENCE

Keep Cincinnati Beautiful January 2015 – Current
- Created new mulch beds, planted numerous flowers, and picked up waste

Bearcat Buddies January 2015 – May 2015
- Tutored students weekly in a lower income school system

SKILLS

- MATLAB Programming
- AutoCAD
- ArcGIS
- 75+ words per minute typing speed
- Microsoft Office applications
- Excellent communication/teamwork skills

EXTRA CIRICULUAR ACTIVITIES

- Table Tennis Club
- Mountaineering Club
- Environmental Engineering Club

Qianhui Xia
481 Wood Duck Dr., Cincinnati, OH, 45246
(513) 410-5880 / xiaqu@mail.uc.edu

EDUCATION

University of Cincinnati, Cincinnati, Ohio
Bachelor of Science in Environmental Engineering May 2019

- *College of Engineering and Applied Science*

CAREER EXPERIENCE

Researcher
University of Cincinnati, Cincinnati Ohio Full-time, January 2018 to August 2018

- Collected the concentration of specific pollutants for air quality study
- Evaluated and analyzed data collected by MATLAB

University of Cincinnati, Cincinnati, Ohio Full-time, May 2017 to August 2017

- Examined the quality of recycled waste oil by determining Free Fatty Acid percentage
- Participated in a team to investigate an efficient way to inexpensively produce biodiesel using recycled oil
- Optimized ratio of reactants to lower costs of biodiesel production
- Produced a large quantities of biodiesel to supply UC Utilities

Teaching Assistant
Elementary School, Xi'an, China Volunteer, September 2011 to January 2012

- Demonstrated outstanding math knowledge to assist students with their study
- Developed communication with students

TECHNICAL SKILLS

MATLAB, ArcGIS, HTML, Microsoft Office Suite

LANGUAGE:

Chinese: native language

ACTIVITY

Participated UC Scholar Showcase April 2018

- Prepared the poster with arranged and processed data
- Lectured audiences about the project about Air quality concentration

Participated in UC Lunar Year Gala February 2016

- Organized performers to share my culture with the university

AWARDS

UC Global Scholarship 2015

- Awarded to international students who demonstrate academic excellence

AVAILABILITY

Available after May 2019

9.7. Appendix G: Request for Proposal

Environmental Engineering Senior Capstone Project
University of Cincinnati

Sonsor: Greater Cincinnati Water Works

Determining the Extent of Lateral Dispersion in the Ohio River:
Combs-Hehl Bridge to the Little Miami River Confluence (Ohio River Miles 461.9 to 463.3)

Greater Cincinnati Water Works (GCWW) is interested in determining the amount of lateral dispersion under a variety of flow conditions in the Ohio River from the Combs-Hehl Bridge to the mouth of the Little Miami River. The project will include tracer (dye) studies on the Ohio River and computer flow modeling.

Introduction

The Ohio River is the source of drinking water for the majority of the residents and businesses in the Cincinnati and Northern Kentucky region. GCWW and the Northern Kentucky Water District (NKWD) operate water treatment plants upstream of downtown Cincinnati with water intakes located near the California area of Cincinnati. GCWW operates the 240 million gallon per day (MGD) Richard Miller Treatment Plant (RMTP), while NKWD operates the 44 MGD Ft. Thomas Treatment Plant. The intakes for both plants are located approximately 1 mile downstream of the Combs-Hehl Bridge on I-275 (Figure 1).

GCWW and NKWD, along with support and participation by the Ohio River Valley Water Sanitation Commission (ORSANCO), have created a collaborative regional source water protection program called the Ohio River Source Water Alliance (ORSWA). The purpose of the source water protection program is to identify and mitigate risks to the quality of source drinking water as the first barrier in a multi-barrier water quality protection strategy.

As part of the source water protection activities, the Combs-Hehl Bridge has been identified as a high-priority potential source of contamination. Based on available statistics, up to 10 trucks carrying DOT-listed hazardous material cross the bridge every hour. Storm water on the bridge is currently collected by catch basins along the edges of the bridge deck that drain directly to the river below. A photograph of the bridge is provided in Figure 2 and the storm water drains are shown in Figure 3. Due to the design of the storm water system, a spill resulting from a vehicle accident or any fluids associated with a vehicle fire would be quickly discharged to the river upstream of the drinking water intakes. Given that the flow velocity in the Ohio River ranges from approximately 0.5 mph to 4 mph, the resultant discharge could impact the drinking water intakes within 15 minutes to two hours, which does not give the utilities much time to react and cease raw water pumping.

The preliminary protection strategy currently under consideration is a diversion system to be installed on the bridge's storm water system. Instead of draining directly downward to the Ohio River, storm water and spills will be collected from the bridge deck and then piped to the Ohio side of the river where they will be discharged. This diversion will in principle allow contaminants to flow past the intakes without being pulled into the treatment plants. This strategy does not protect the river as a whole from contamination, but if successful it will protect the drinking water supply.

Modeling

A computational model will be used to predict the contaminant dispersion under a variety of flow characteristics including the 10th and 90th percentile flows as well as the median flow. The model must accommodate dispersion throughout the water column (i.e., true 3 dimensional flow model).

The modeling phase includes:

- Evaluating 3-D dispersion simulation models.
- Recommending an appropriate model with justification.
- Creating a new 3-D model if none are available.
- Determining data requirements and gather appropriate data for model simulations.
- Calibrating the model using data generated during the tracer study, including bathymetric and flow velocity data.
- Using the model to determine the minimum distance across the bridge where a spill diversion system needs to be designed to achieve the protection goals under a variety of flow conditions.

Deliverables

Fall Semester

The following tasks should be completed by the end of the Fall Semester.

- Completion of the tracer study and preparation of a report on the results.
- Evaluation of possible 3-D models that could be used to simulate chemical dispersion in the Ohio River and preparation of a proposal report that recommends the best model.
- Provide a presentation to the Sponsor that covers the tracer study and recommendation of the most appropriate model.

Spring Semester

The following tasks should be completed by the end of the Spring Semester.

- Develop or implement an existing 3-D simulation model for the Ohio River.
- Calibrate the model using gathered data and data from the tracer study.
- Recommend a minimum distance the spill/storm water diversion system must extend across the span of the bridge based on the model results for median river flow as well as the 10th and 90th percentile flows.
- Use the model to show how contaminants will disperse in the Ohio River from the Combs-Hehl Bridge to the mouth of the Little Miami River from the spill diversion point recommended using a realistic spill scenario.
- Prepare a final report that includes the tasks from the Fall Semester and the Spring Semester.
- Provide a presentation that covers the key items in the final report.

The final report should include maps and cross sections of the river showing the dispersion of the contaminants and any impact to the intakes. If possible an animated output showing the spread of the plume through the study area is desirable. In addition, an electronic copy of the model along with documentation and any code generated should be supplied to the Sponsor so that alternative scenarios can be evaluated in the future.

Figure 1. Project Study Area

Figure 2. Combs-Hehl Bridge with GCWW and NKWD intakes in left-center of picture

Figure 3. Example of Current Downspout and Storm Water Drain

Figure 4. Example of Previous Ohio River Dye Study

Figure 5. GCWW Intake (foreground) and NKWD Intake (background)