Thermal Plume Modeling: A Tool for Regulatory Compliance

By Greg Howick, Ph.D., and Terry Larson, P.E.

Electric power plants with steam-powered generators typically use water to cool and condense the steam for return to the boiler. The heated and sometimes briny cooling water is discharged into lakes, rivers, estuaries and oceans, and does not immediately disperse in the cooler receiving waters. The resulting plume is subject to water quality standards promulgated under the Clean Water Act and regulated through National Pollutant Discharge Elimination System permits.

An area extending from the end of the discharge pipe where the discharge can legally cause water quality standards to be exceeded is called the mixing zone. The size, shape, and conditions for use of mixing zones vary among states and types of receiving waters. For most discharges into rivers and streams, water quality standards outside the mixing zone must be met at all ambient flow conditions down to the seven-day average low flow that recurs once in ten years (7Q10).

Although measuring the extent of a thermal plume in the field is relatively easy, being present to take measurements when ambient water temperature is highest and river flow is at 7Q10 is extremely unlikely. A plume model can extend the analysis to the rare conditions stipulated in water quality regulations. For new power plants, plume modeling can be used to determine how the discharge will dissipate in the receiving water under varying ambient conditions and different outlet configurations.

Plume modeling can aid in plant design and provide solid evidence to regulators in support of discharge limits. Burns & McDonnell scientists currently model discharge plumes using the CORMIX (Cornell Mixing Zone Expert System) hydrodynamic mixing zone computer simulation. Developed for the U.S. Environmental Protection Agency, CORMIX emphasizes predicting the geometry and dilution characteristics of pollutant plumes to assess regulatory compliance. Information required for CORMIX includes bathymetry, flow or tidal regimens; water quality of the receiving water in the vicinity of the discharge, geometry of the discharge structure and the quantity and quality of the discharge.

The example of a new combined-cycle, combustion turbine power plant that proposed to discharge blowdown from cooling towers into a large Midwestern river illustrates the utility of CORMIX. The proposed discharge would enter the river through a small channel at an angle perpendicular to the direction of river flow. Unfortunately, the discharge site was habitat for a known population of freshwater mussel species protected by the Endangered Species Act. The U.S. Fish and Wildlife Service agreed to allow the discharge if the mixing zone was limited to a rectangle extending 15 meters from shore and 30 meters downstream from the discharge, and if the mussels in that rectangle were relocated. Plant designers needed to know the maximum effluent temperature that could be discharged into the river given these limits on the mixing zone.

CORMIX simulations indicated that both discharge temperature and river flow rate affected the size and shape...
of the plume. Increasing the temperature of the discharge increased the downstream length of the plume and the distance the plume extended from shore. Plume distance from shore was greatest at the lowest river flow tested. As river flow increased, the plume was more quickly turned downstream and distance from shore decreased (Figure 1).

Plume length was found to be greatest at approximately the average river flow rate. At flow rates below the average, the lower river flow rates carried the plume farther downstream before dispersing. However, the plume was narrower, with less total area than at average flow conditions. At flows above the average, increasing river flow rate generated more turbulence and dilution, which increased dispersion and decreased plume length and area (Figure 2).

For each month, plume lengths and distances from shore were determined over ranges of discharge temperatures, river temperatures, and river flows. Based on modeling results, a maximum permitted plume size of 30 meters in length and within 15 meters of the shore was established, and the maximum discharge temperatures that would generate such a plume were interpolated for each month. In addition to temperature, total dissolved solids and sulfate concentrations in the discharge were of potential concern. CORMIX was also used to simulate the plumes for these parameters. These plumes were found to be smaller than those produced by the maximum allowable discharge temperatures (Figure 3).

Using a hydrodynamic plume model proved to be a relatively rapid and inexpensive method for evaluating numerous conditions to find the maximum discharge temperatures that would meet regulatory requirements. Discharge limitations can influence facility site selection and design.

Determination of a facility’s discharge plume early in the design phase can smooth the discharge permitting process and prevent costly redesign work.

**Greg Howick** is an aquatic ecologist in the Environmental Group. He earned his bachelor’s degree in biology from Ithaca College, his master’s degree in zoology from the University of Maine, and his Ph.D. in biology (limnology & aquatic ecology) from the University of Kansas. He has more than 20 years experience in basic & applied limnological research.

**Terry Larson** is a civil engineer in the Energy Group. He received his bachelor’s degree in civil engineering from the University of Nebraska-Lincoln, and is a registered professional engineer in Missouri, Nebraska, Arizona and Indiana. He has more than 16 years experience in power-related projects.