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STATE OF ILLINOIS
Pollution Control Board

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
Petition of Noveon, Inc.	)	
	)	**AS 02-5**
	)	
for an Adjusted Standard from 35 Ill. Adm. Code 304.122	)	

NOTICE OF FILING

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PLEASE TAKE NOTICE that on **Friday, February 6, 2004**, we filed the attached **Expert Written Testimony of Michael R. Corn, P.E.** with the Illinois Pollution Control Board, a copy of which is herewith served upon you.

Respectfully submitted,

NOVEON, INC.

By: [signature]
One of Its Attorneys

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EXPERT WRITTEN TESTIMONY
OF MICHAEL R. CORN, P.E.

1. INTRODUCTION

This Expert Written Testimony is submitted to the Illinois Pollution Control Board in connection with the Petition for Adjusted Standard before the Illinois Pollution Control Board entitled Noveon, Inc. versus Illinois Environmental Protection Agency, PCB as 02-5.

2. QUALIFICATIONS AND EXPERIENCE

I am the President and a Technical Director of **AquAeTer, Inc.**, **(AquAeTer)**, located in Brentwood, Tennessee. **AquAeTer** has three offices, one of which is the Brentwood office, and a staff of about 25 professionals. In my technical role for the company, I serve as the chief water quality monitoring, modeling and permitting engineer. As such, I direct our projects in dispersion monitoring and modeling, water quality monitoring and modeling, including total maximum daily load analyses, contaminant transport, fate and effects monitoring and modeling.

I have approximately 28 years experience in environmental engineering and I have worked in most states and in 20 foreign countries. I have participated or directed water quality studies on over 200 streams, rivers, lakes, estuaries, and oceans in both the U.S. and in foreign countries. I have actively directed dispersion studies and regulatory interpretations of mixing zones on over 55 water bodies in 21 states and three foreign countries.

I have presented expert opinions and have given expert testimony on mixing zones in Connecticut and Illinois. I have given an expert opinion before the Illinois Pollution Control Board (Board) in Chicago, Illinois on the theory and the size of mixing zones in proposed Illinois Environmental Protection Agency (IEPA) mixing zone regulations. The Board agreed with the premise I put forward and a minimum size limitation of 1,000 square feet for a Zone of Initial Dilution (ZID), as proposed by the Illinois Environmental Protection Agency IEPA, was removed from the regulations.

I hold a Bachelor of Science Degree (B.S.) from the University of Tennessee in Nuclear Engineering and a Master of Science Degree (M.S.) from Vanderbilt University in Environmental and Water Resources Engineering.

My resume is attached, including expert opinion or testimony given on mixing zones.

3. DESCRIPTION OF EFFLUENT AND RIVER

Effluent Flow and Characteristics

The Noveon facility at Henry has an average effluent flow of 0.8 million gallons per day (mgd) or 1.24 cubic feet per second (cfs) and a maximum flow of 1.35 mgd or 2.09 cfs. The wastewater treatment facility provides treatment for adjustment of the pH or acidity of the wastewater, removes organic oxygen demanding material or carbonaceous biochemical oxygen demand (CBOD), and removes solids, as more fully described by Mr. Flippin. The effluent discharge meets the permitted treatment requirements and based on the data collected for monthly Discharge Monitoring Reports (DMRs) by the Henry facility, the effluent quality is summarized below:

1. 5-day CBOD or $CBOD_5$ mass loadings average less than 135 lbs/day, which represents a treatment efficiency of greater than 96 percent removal efficiency through the treatment facility (secondary treatment is considered 85 percent removal efficiency).

2. The pH in the Noveon effluent normally runs around 7.2 standard units (S.U.) or near neutral pH.

3. The Henry facility uses amines in the manufacture of its products. These amines are converted to ammonia through a process known as hydrolysis in the wastewater treatment facility. Ammonia measurements made by IEPA and by Noveon or their contractors indicate that ammonia concentrations in the effluent average around 900 pounds per day (lbs/day) or 135 mg/L.

4. The total dissolved solids (TDS) or salt content of the effluent ranges from about 6,000 mg/L to greater than 10,000 mg/L. The wastewater treatment facility does not remove salt nor is there a treatment technology economically feasible for salt removal.

The City of Henry POTW also discharges through the Noveon single-port diffuser. The total flow from the Henry POTW is around 0.3 mgd or 0.45 cfs. The POTW effluent is mixed in the pipe with the Noveon effluent and the total flow of the two discharges is around 1.1 mgd or 1.7 cfs.

River Flow and Water Quality Characteristics

The Illinois River flow varies based on the season with the lowest flows occurring during summer and early fall months. The IEPA regulations require that mixing zones be established for the 7-day 10-year low flow (7Q10) or the flow that has a 10 percent (%) chance of occurring in any given year. Because statistically, flow varies by rainfall and month of the year, the 7Q10 flows for the critical months of April to October were determined for each month, which gives a statistically equivalent 7Q10 flow for the individual month, as follows:

Summer Month	7Q10
April	6,900 cfs
May	5,500 cfs
June	5,900 cfs
July	4,400 cfs
August	3,700 cfs
September	2,900 cfs
October	4,300 cfs

These 7Q10 flows calculated for each summer month to statistically determine the most critical low flow were determined from the U.S. Geological Survey (USGS) gage at Henry for the years 1982 through 1993. The Illinois State Water Survey has calculated a 7Q10 low flow of 3,400 cfs based on data from all months of the year.

The average yearly flow in the Illinois River is around 15,300 cfs, with the monthly average flows ranging from a low monthly average of around 8,800 cfs in August to a high monthly average of around 26,400 cfs in March.

The water quality characteristics of the Illinois River were obtained from the USEPA store database for the Hennepin monitoring site for the years 1977 to 1994 and are described below.

1. Background pH in the River was calculated as 7.7 S.U. for the critical summer period.
2. DO concentrations in the River upstream from the Henry facility are at saturation during the September critical period and DO downstream from the Noveon facility is around 94 to 96 % of saturation. The water quality standard for DO is 5 mg/L or for a September temperature of around 25 °C (77 to 78 °F), this represents about 61 % of saturation.
3. Background ammonia concentration (NH_4 + NH_3) in the River is 0.09 mg/L during the summer months and background organic nitrogen is around 1 mg/L.
4. Background TDS in the River during the summer low flow period is around 350 to 500 mg/L.

Data for the winter indicate that these months are not limiting periods for ammonia discharges.

4. LOCATION OF DISCHARGE POINT AND PHYSICAL CHARACTERISTICS OF THE DISCHARGE

The Noveon single-port diffuser is located at about Illinois River mile (IRM) 198, as shown on Figure 1. The discharge pipe is a single port placed along the bottom of the river and discharging perpendicular to river flow. The port is 18 inches in diameter. The discharge of the effluent, although initially at a perpendicular angle to the River flow, rapidly reflects in the ambient current to a downstream direction, as shown in Figure 2. Local water depths in the plume trajectory are about 13.5 ft. The effluent exit velocity of around 1 ft/sec is high when compared to the river velocity at low flow of around 0.3 ft/sec. The effluent is negatively buoyant, meaning it is denser than the river water, due to salt, but the effluent/river mixture would be approaching neutral buoyancy near the downstream edge of the ZID. A single-port diffuser is an engineered structure that provides rapid and immediate mixing.

5. DEFINITION OF TERMS

Mixing of an effluent or a tributary stream entering a river is a natural phenomenon that allows the two waters to mix and reach equilibrium where the two are totally mixed. The mixing of two independent water streams into each other can be physically described through very well-developed and recognized mathematical formulas of dispersion. Mixing zones have also been included in almost all states water quality regulations as a combination of the mathematical descriptions and also prescriptive definitions that minimize the areas of the mixing zones so as not to affect the aquatic resources or other uses of the river system. Federal guidance on mixing zones has been provided by the U.S. Environmental Protection Agency (USEPA) in the document, "Technical Support Document for Water Quality-based Toxics Control" (TSD; USEPA March 1991) and by the Illinois Environmental Protection Agency (IEPA) in the document, "Illinois Permitting Guidance for Mixing Zones". There are several definitions and acronyms used to describe mixing zones in both guidance documents and these are defined below.

Physical Descriptions of Mixing Zones

Physical mixing of a tributary or an effluent discharge (the entering stream) that enters into a larger body of water (the receiving stream), such as the Illinois River, occurs because the entering stream of water normally has enough physical energy, either through the entering velocity being greater than the receiving stream or there is a density gradient between the entering stream over that of the receiving stream. This allows the entering stream to force its way into the receiving stream, similar to a car entering the freeway from a merging lane. The entering stream will blend through natural mixing processes until it is in total equilibrium or totally mixed with the larger body of water (i.e., the entering stream and the receiving stream are at equilibrium concentration and density). Until the mixing of the entering stream and the receiving stream are in equilibrium, a definitive plume where the entering stream and the receiving stream are at different concentrations and densities occurs. This plume can be described and predicted mathematically as discussed next.

The mixing zone for an entering stream, either an effluent discharge or a tributary, is divided into a near-field zone, described as a zone of rapid and immediate mixing caused by the energy of the entering stream dispersing into the receiving stream, and a far-field zone, described as mixing by the natural ambient diffusion of the receiving stream slowly incorporating the plume into the whole body of water available. The near-field mixing zone occurs quite rapidly, on the order of a few minutes or less, and the far-field zone mixing occurs much slower, on the order of an hour or more. The physical mixing zones in a plume are depicted in Figure 3.

Near-Field Zone. The near-field zone is defined as the turbulent zone at the discharge point where rapid and immediate mixing occurs due to the immediate mixing of a high energy stream with one of lower energy. Aquatic life will not reside in this zone due to the turbulence. This zone consists of a Jet Momentum Zone, a restratification zone (dependent on plume/river density differences after the jet zone), and a transition zone, the buoyant spreading zone, which is a mixing area where the plume goes from effluent-dominated mixing to mixing totally dominated by river ambient diffusion (natural energy and dispersive, spreading-out, forces of the receiving stream). When an entering stream, such as, an effluent discharge, flows into a receiving stream, it normally has an excess velocity over the receiving stream itself. In the case of the Noveon discharge, the port exit velocity is about 1 foot per second (ft/sec) and the river velocity is about 0.3 ft/sec. This excess velocity allows the effluent to push its way into the river until the river/effluent mixture reaches an equilibrium velocity. Additionally, the Noveon discharge is heavier than the river water and this density difference also causes the effluent plume to have momentum or momentum generated by gravitational spreading. The effluent/river mixture in the near-field zone is dragged by the river in a downstream direction and after a few minutes of this rapid and immediate mixing, the plume mixing will be dependent entirely on the river ambient dispersive forces, which will spread the plume out longitudinally, or downstream direction, vertically, or with depth, and laterally, across the river. For the Noveon discharge, the near-field zone is on the order of about 100 ft before far-field mixing becomes dominant.

Far-Field Mixing. The far-field zone consists of the buoyant spreading zone (actually a transition zone between the near-field and far-field zones) and the ambient diffusion zone, where dispersion is totally dependent on a much slower process called ambient diffusion or spreading out of the plume, longitudinally, vertically and laterally. The river velocity is in a downstream direction, so the plume spreads out most rapidly in a downstream direction. The plume mixes vertically according to density. For the Noveon discharge, the plume is denser than the river (i.e., the plume wants to sink or be near the bottom of the river, and full vertical mixing occurs about 850 ft downstream. Because the longitudinal dispersion is the most rapid due to the velocity vectors being in a downstream direction, the maximum concentrations or density in the plume is along the centerline of the plume in a downstream direction. For the Noveon discharge, the plume spreads out in all directions, but the plume centerline maximum concentrations are along a narrow width in a downstream direction, on the order of about 150 ft wide.

Actual Mixing Zone. The actual mixing that occurs between the Noveon discharge and the River has been physically monitored and mathematically modeled. The mixing zone monitored in the Illinois River has been shown in Figure 2. The near-field mixing including the jet momentum zone through the early phases of the buoyant spreading region is about 100 ft long (see conductivity isopleth line of 2,000 micromhos per centimeter or umhos/cm, which is equivalent to approximately 1,280 mg/L of total dissolved solids or salt). The dispersion at the end of this near-field mixing zone is around 20:1 or more. The plume is vertically mixed from top to bottom at about 850 ft downstream and the plume width is about 150 ft wide at this point. The dispersion achieved at the downstream edge of the plume at about 1,000 ft downstream is 100:1 or more. The existing single-port diffuser is effective in dispersing the effluent into the Illinois River and the effluent has been and will continue to meet water quality and whole effluent toxicity limits in this mixing zone.

Regulatory Mixing Zone

Mixing zones have been allowed in the U.S. since the late 1960's and they are used to provide protection to the receiving stream when treatment technology or costs prevent achievement of the numeric or whole effluent toxicity standards in the discharge itself. The National Academy of Sciences in 1972 defined mixing zones in terms of limiting the exposure time and concentration to 1-hour for aquatic species passing through a plume, as shown in Figure 4. The U.S. Environmental Protection Agency (USEPA) still uses this time concept in their guidance on mixing zones. Several goals of mixing zones are outlined in the USEPA Technical Support Document for Water Quality-based Toxics Control (TSD, March 1991) and these goals are described below:

a. Achieve maximum dispersion in the smallest area possible;
b. Minimize the effects on the receiving water;
c. Minimize acute and chronic toxicity in the receiving water;
d. Meet narrative water quality standards within the defined mixing zone;
e. Provide maximum protection for the receiving water, even under upset or abnormal events;
f. Maintain a Zone of Passage for fish;
g. Meet the IEPA water quality regulations; and
h. Meet the TSD Guidance on mixing zones.

In order to achieve these goals, IEPA has specified in their Mixing Zone Permitting Guidance several requirements that mirror the USEPA TSD guidance. Specifically, IEPA allows the following:

1) Zone of Free Passage, which establishes the maximum volume of river flow that can be used for mixing in the Near-Field Zone,

called the Zone of Initial Dilution (ZID) and/or the Far-Field Zone, called the Total Mixing Zone (TMZ);

2) Zone of Initial Dilution or ZID, establishes a regulatory zone where acute numeric and whole effluent toxicity are allowed until this initial rapid and immediate mixing is completed; and

3) Total Mixing Zone or TMZ, establishes a regulatory zone where chronic numeric and whole effluent toxicity are allowed for some distance downstream limited by 26 acres and 25 % of the volume of flow or cross-sectional area.

Zone of Free Passage. IEPA has specified a Zone of Free Passage for fish that gives an upper bound for the volume of river flow that can be used to disperse an effluent in the river. The IEPA guidance states:

> "The 25 % of cross-sectional area or volume of flow establishes the extent of the Zone of Passage given at 35 Ill. Adm. Code 302.102(b) (6) for mixing situations where the upstream flow to effluent dilution ratio is 3:1 or greater."

IEPA has also specified a maximum area for a mixing zone of 26 acres that would be bounded by a width determined from this Zone of Free Passage requirement. A total length of the mixing zone can then be calculated from the 25% of volume or cross-sectional area restriction and the 26-acres restriction. IEPA has permitted both a Zone of Initial Dilution (ZID) and Total Mixing Zones (TMZ) based on the ZID volume of flow allowed. Mixing zones rarely require the full 26 acres to achieve water quality standards and Noveon has asked for less than 5 acres for the TMZ.

Zone of Initial Dilution (ZID). The ZID or Zone of Initial Dilution is defined as the zone of immediate and rapid mixing, as depicted previously in Figure 3. The ZID was conceptually introduced by the National Academy of Sciences in 1972, as shown in Figure 4. USEPA lists in the TSD several criteria for defining a ZID:

1. Use a high-velocity diffuser with port exit velocities greater than or equal to 10 ft/sec to limit exposure to only a few minutes (i.e., 3 minutes). For multiport diffusers, the TSD specifies, "...hydraulic investigations and calculations indicate that the use of a high-velocity discharge with an initial velocity of 3 meters per second, or more, together with a mixing zone spatial limitation of 50 times the discharge length scale in any direction, should ensure that the CMC (Criterion Maximum Concentration or acute toxicity limit) is met within a few minutes under all conditions". IEPA does not use the fundamental time limitation, but does refer to the spatial limitation of 50 * the discharge length scale or in the case of a diffuser, 50 * square root of the cross-sectional area of a single port.

   The time is the fundamental basis for USEPA's definition of a ZID, although IEPA does not use this as a basis for the ZID. The discharge length scale criterion is not a fixed length, but rather a requirement to meet a minimum time and the discharge length scale is a way to estimate that this minimum time is met for almost all discharges. The 50 times the cross-sectional area of a single port approximates the distance known as the Zone of Flow Establishment, as shown in Figure 5, and is a zone where effluent momentum dominates the dispersion. This is only a small part of the physical hydraulic zone of rapid and immediate mixing, as presented in Figure 6. The actual jet momentum zone extends to approximately just beyond where the edge of the plume reaches the surface, as depicted in Figure 7. The rule of thumb for the Jet Momentum Zone downstream from a diffuser is on the order of one diffuser length (i.e., 0.5 to 1.5 * diffuser length). This distance is dependent on river velocity and the jet momentum shrinks at low river velocities or flows, and elongates at high river velocities or flows.

2. For other discharges that don't meet the 10 ft/sec port exit velocity criterion, e.g., but still achieve rapid and immediate mixing, the USEPA and IEPA use three methods to determine the ZID which are:

    a. 50 times the square root of the cross-sectional area of the port (port diameter is 1.5 feet) = 66.5 ft ZID length for the Noveon single-port diffuser;
    b. 5 times the local water depth (depth = 13.5 ft) = 67.5 ft; and
    c. 10 % of the total mixing zone (allowable mixing zone length defined by 26 acres divided by width of 25 % of the cross-sectional area or about 250 ft for the Illinois River at Noveon) ~ 4,530 ft; Noveon requested 1,000 ft total mixing zone. Under this total mixing zone TMZ length, the ZID would be 10 % of the 1,000 ft or 100 ft in length

From these three scenarios, a ZID distance of 66 ft was determined and, a dispersion of 13.2:1 was determined for the single-port diffuser during the summer (limiting condition). With both the Noveon and Henry POTW discharging through the single-port diffuser and using the background temperature, pH and total ammonia values from the upstream monitoring station, a total ammonia concentration of 155 mg/L could be discharged from the Noveon single-port diffuser and meet the IEPA water quality standards at the downstream edge of the ZID (point of maximum concentrations).

It is important to note that, in each of these ZID length determinations, the USEPA and, therefore, IEPA specify that these lengths are to be met in "any spatial direction". USEPA defines spatial as a ***discharge length scale*** or distance is defined in each of these cases as a length along the centerline of the plume. In free-flowing streams, such as, the Illinois River (versus tidal two-dimensional flow situations), this length is defined in the downstream flow direction or along the length where maximum plume concentrations occur. The 25 % of cross-sectional area or volume of flow specifies a method to define the maximum volume of water available for mixing, either in the ZID or in the TMZ and is used as one dimension in defining the total allowable length of the mixing zone or 26 acres divided by a width equivalent to the 25% of volume or cross-sectional area in order to give a total length allowable. The intent of the mixing zone is to achieve maximum dispersion in the smallest area possible and therefore dispersion in the ZID should be maximized.

IEPA has specified for other discharges with permitted mixing zones that spatial direction in mixing zones downstream from high-rate multiport diffusers is in the direction of flow, e.g., American Bottoms Regional Wastewater Treatment Faciltiy in Sauget, Illinois; Olin Chemical in East Alton, Illinois; 3M in Cordova, Illinois; and Rock River Water Reclamation District in Rockford, Illinois and has used the actual hydraulic mixing zone to establish the dispersion in the ZID.

In keeping with the original concept of mixing zones, USEPA also states "that a drifting organism would not be exposed to 1-hour average concentrations exceeding the CMC". The CMC is the Criterion Maximum Concentration or the concentration that would cause acute toxicity. In reality, drifting organisms would be swept downstream within a few minutes of entering the ZID downstream from the Noveon diffuser.

Total Mixing Zone (TMZ). The TMZ is the zone that is bounded by a width of 25 percent of the cross-sectional area or volume of flow in the River and a total area of 26 acres. The numeric water quality criteria and whole effluent chronic toxicity must be met at the downstream edge of this mixing zone. The maximum concentrations in a mixing zone are along the centerline of the plume, as shown in Figure 8 and all mixing zones, as well as, ZIDs are based on meeting the standards for the maximum concentrations along the centerline of the plume. The length of this zone is not defined by USEPA other than in original mixing zone documents as a time constraint of 1 hr of total exposure for a mobile aquatic organism, as previously shown in Figure 4. IEPA defines the TMZ as a total area of 26 acres, which would be bound by a defined width of 25 percent of the cross-sectional area (width times depth). Since the Illinois River at the site is 850 ft wide at low flow, the width can be conservatively defined as at least 250 ft, as presented in Figure 9, and the length can be calculated as follows:

(26 acres)(43,560 sq ft/ac)/250 ft = 4,530 ft

Noveon has defined the TMZ in their joint mixing zone with the POTW discharge as having a length of 1,000 ft giving a total area of about 5 acres or less than one-fifth of the total area actually allowed under the Illinois mixing zone guidance.

Enhancements to Dispersion

There are several engineering designs that can enhance the mixing of an effluent into a receiving stream, such as the Illinois River. The most common engineered structures being used today are either a single-port diffuser placed near the channel bottom or a multiport diffuser placed near the channel bottom.

<u>Single-Port Diffuser.</u> A single-port diffuser is a single pipe located on or near the bottom of the river that disperses the effluent rapidly and immediately into the river. Single-port diffusers achieve a greater dispersion than the original side-channel surface discharges that were common prior to the 1980's to 1990's and dispersion of 10:1 or more can be achieved within a short distance downstream from these types of diffusers. In the case of the Noveon single-port diffuser, a dispersion of 13:2:1 is achieved within a short distance downstream from the discharge. The existing single-port diffuser meets chronic numeric criteria and chronic whole effluent toxicity at the typical discharge conditions at about 500 to 1,000 ft from the diffuser, depending on flow.

<u>Multiport Diffuser.</u> A multiport diffuser is a pipe with multiple discharge ports that would discharge the effluent so that the effluent exit velocity from each port is at least 10 ft/sec in order to achieve rapid and immediate mixing. A multiport diffuser spreads the effluent out over the length of the diffuser and achieves greater dispersion by supplying greater energy (10 ft/sec exit velocity) for jet momentum into the receiving stream at each of the individual ports. Multiport diffusers have been installed for effluent discharges since about the late 1980's and this type of diffuser is currently the best technology for ensuring stream water quality standards are met under almost all conditions. A multiport diffuser, as depicted in Figure 10, has been conceptually designed for the Noveon discharge to replace the existing single-port diffuser. Both the ZID and the TMZ distances are physically dictated by the ambient velocity in the River or flow with the plume elongated at high flows (pushed further downstream) and mixing closer to the diffuser at low flows (diffuser discharge energy causes plume to mix more quickly in lower ambient currents). The dispersion that will be achieved from this diffuser at the edge of the ZID has been projected at 43:1 at a downstream distance of less than 50 ft (on the order of 15 ft downstream). All acute numeric criteria and acute whole effluent toxicity will be met at the edge of the ZID. The multiport diffuser will meet chronic numeric criteria and chronic whole effluent toxicity within about 100 to 250 ft from the diffuser. The projected plume from the diffuser is presented in Figure 11.

6. REGULATORY AND HYDRAULIC ZIDs AND TOTAL MIXING ZONES

Regulatory ZIDs have been defined to minimize the time of exposure for organisms passing through the mixing zone to acutely toxic constituents, e.g., salt. To ensure that this time is minimized to just a few minutes, the regulators have used partial ZID hydraulic descriptions to give minimum guidance lengths for a ZID. USEPA defines the hydraulic definition of the mixing zone as two zones:

1. Mixing and dilution in the first stage are determined by the initial momentum and the buoyancy of the discharge, which is the actual ZID or near-field mixing zone.
2. The second stage of mixing covers a more extensive area in which the effect of initial momentum and buoyancy is diminished and the waste is mixed primarily by ambient turbulence.

Both of these zones are influenced by the effluent discharge itself, as well as, the flow in the river. The first stage of hydraulic mixing, which is dominated by the energy of the effluent discharge itself, is normally hydraulically described as the jet momentum zone, where the plume expands to mix with the total amount of ambient water passing over the port. This jet zone normally is mathematically projected until the edge of the plume interacts with the surface, as depicted previously in Figure 7. At this point, the plume has reached the surface and physically one can sometimes see a boiling or turbulence at the surface where this occurs. At this point, the plume will undergo further buoyant spreading due to any density difference between the plume and the ambient river water. The buoyant spreading zone is a gravitational spreading region where density differences provide a momentum driver. Different hydraulic mixing zone models, (e.g. UDHKDEN, CORMIX), approved by the USEPA, use the point or a short distance downstream from this point in estimating the ZID.

The second stage is dominated totally by the ambient diffusion of the river and is hydraulically described as the far-field mixing zone. The buoyant spreading region is for the most part a transition zone between the near-field and the far-field zones and is often divided to be a part of both zones. The effluent plume will eventually mix in the ambient currents until it is completely mixed in the total river flow. Mathematically, we divide the river up into boxes with equal widths and transfer or mix the plume to the closest box out from the plume and then to the next box, etc. This transfer across the whole width of the river takes a considerable distance or time, since swimming against the current is harder than swimming downstream with the current. This will not normally occur in a River such as the Illinois River until several miles (on the order of 10 or more miles) downstream from the discharge. IEPA, as well as most other states, limit the volume of flow or cross-sectional area for mixing zones to about 25% of the flow and IEPA also limits the total length by setting a maximum area for the mixing zone of 16 acres.

7. WATER QUALITY EFFECTS

Toxicity

Both ammonia and salt have been identified from laboratory bioassay tests on fathead minnows and water fleas as causing acute toxicity in the Noveon effluent. It is noted that this is based on laboratory toxicity tests and it is important to note that given the rapid mixing of the Noveon discharge, there are no impacts on aquatic life in the River resulting from the Noveon discharge. With the mixing zone downstream from the existing single-port diffuser and the projected mixing zone downstream from the multiport diffuser, the identified toxicity in the EA Engineering toxicity report would not impair water quality in the River.

Ammonia or NH_3. Ammonia exists in the environment both as the ionized form, NH_4, which is not toxic, or as the unionized form, NH_3, which can be toxic to both fathead minnows and water fleas in laboratory tests. Ammonia is converted to more of the unionized NH_3 as pH reaches 8 standard units (S.U.) and above. The pH of the effluent is near a neutral pH of 7, but the Illinois River has a pH of around 7.8 during critical periods. With the current single-port diffuser and the combined discharge of Noveon and the Henry POTW, the Noveon effluent ammonia concentrations can be around 155 mg/L and meet the ammonia acute water quality standard at the edge of the ZID, as defined by the IEPA ZID limitation of 50 * square root of the cross-sectional area of the port. Because the effluent ammonia was measured one time at around 200 mg/L, a multiport diffuser that would give a dispersion of around 43:1 at the downstream edge of the ZID has been designed and has been proposed for installation in place of the current single-port diffuser. The diffuser would provide maximum protection to the River in the shortest distance and smallest area. The diffuser design is presented in Figure 10. There has been no water quality or toxicity problems observed in the vicinity of the Noveon diffuser and the existing physical mixing zone has been effective.

Salts. Ammonia has been consistently listed by IEPA as the primary toxicant in the effluent, but salt has most likely been a more consistent or at least as consistent constituent in the effluent that causes laboratory toxicity in effluent samples.Total dissolved solids consisting primarily as sodium chloride or NaCl (commonly used as table salt) is also toxic to fathead minnows and water fleas. A dispersion of around 7 to 9:1 is required to prevent effluent toxicity at the downstream edge of the ZID. IEPA had recommended a ZID that would only give a dispersion of around 6:1. This ZID dispersion would not be protective of acutely toxic conditions at the downstream edge of the ZID, even if no ammonia were in the effluent.

Dissolved Oxygen

AquAeTer developed a wasteload allocation model using the USEPA QUAL2E model, data from the Illinois River, and reaeration rates and deoxygenation rates measured on similar size rivers. It was found, that during critical 7Q10 and corresponding high-temperature periods, that the DO concentration in the Illinois River downstream from the Noveon discharge is around 7.5 mg/L, as compared to the DO standard of 5 mg/L for this time period. The model was run with the Noveon discharge with permitted 5-day carbonaceous biochemical oxygen demands ($CBOD_5$) or organic loadings and high ammonia loadings. Both of these demand oxygen from the river as they further naturally decay in the river through natural uptake by resident bacterial populations in the River. When the model was run to simulate no discharge from the Noveon plant, the DO was increased slightly in the downstream reaches by less than 0.2 mg/L. The accuracy of the DO measurement is +/- 0.1 mg/L, so the actual impact to the DO in the River can probably not be measured for all practical purposes. The river meets DO standards based on the available data for downstream locations. Therefore, the Noveon discharge is not impacting DO in the River and DO standards are met.

8. CONCLUSIONS AND OPINIONS

Allowable Discharge of Ammonia

As part of the relief requested in these proceedings, Noveon has requested to install a high-rate multiport diffuser in place of their current single-port diffuser. This multiport diffuser has been designed to achieve a dispersion of 43:1 and an effluent ammonia concentration greater than 220 mg/L could be discharged and still meet IEPA ammonia water quality standards at the edge of the ZID. The diffuser would allow the ZID and TMZ to be met in the smallest area possible and would be protective of the aquatic environment for both ammonia and salt that is contained in the effluent.

Effect, if any, on Water Quality

NH_3 WQ Standards. There has been no observed effect to aquatic species in the Illinois River or to water quality standards in the River based on the current discharge. With the new multiport diffuser, water quality standards for NH_3 will be met for both acute and chronic water quality standards within about 100 to 250 ft from the diffuser. Acute and chronic toxicity for both NH_3 and salt will also be met within this distance. The diffuser will provide the maximum protection for the aquatic environment in the Illinois River.

Dissolved Oxygen. DO is being met in the Illinois River downstream from the Noveon plant with DO being between 94 and 96 % of saturation on average during the critical month of September. A water quality model has been run with the maximum concentrations of CBOD and ammonia from Noveon input into the model. The discharge from Noveon has projected to result in less than 0.2 mg/L oxygen change from a no Noveon discharge scenario. This DO change is less than the accuracy of the DO test of +/- 0.1 mg/L and would be immeasurable in the River. DO in the River at maximum CBOD and ammonia loadings has been projected to be around 7.5 mg/L during critical warm-weather low-flow conditions, as compared to a DO standard of 5 mg/L. This is not unexpected since the low flow in the River of 2,900 cfs in September is still greater than 2,300 times the Noveon effluent flow of 1.23 cfs or the Noveon effluent only represents about 0.04 percent of the flow in the River.