BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

IN THE MATTER OF:	)	
	)	
WATER QUALITY STANDARDS AND	)	R08-9
EFFLUENT LIMITATIONS FOR THE	)	(Rulemaking - Water)
CHICAGO AREA WATERWAY SYSTEM	)	
AND THE LOWER DES PLAINES RIVER:	)	Subdocket B
PROPOSED AMENDMENTS TO 35 Ill.	)	
Adm. Code Parts 301, 302, 303 and 304	)	

NOTICE OF FILING

To: ALL COUNSEL OF RECORD
(Service List Attached)

PLEASE TAKE NOTICE that on the 3rd day of January, 2011, I, on behalf of the Metropolitan Water Reclamation District of Greater Chicago (the "District"), electronically filed the District's **Responses to Information Requests at October 19 and 20, 2010 Hearings**, with the Office of the Clerk of the Illinois Pollution Control Board.

Dated: January 3, 2011

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

By: */s/ Fredric P. Andes*
One of Its Attorneys

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PROOF OF SERVICE

The undersigned, a non-attorney, certifies, under penalties of perjury pursuant to 735 ILCS 5/1-109, that I caused a copy of the forgoing, the District's **Responses to Information Requests at October 19 and 20, 2010 Hearings,** to be served via First Class Mail, postage paid, from One North Wacker Drive, Chicago, Illinois, on the 3rd day of January, 2011, upon the attorneys of record on the attached Service List.

/s/ Barbara E. Szynalik
Barbara E. Szynalik

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

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METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO'S RESPONSES TO INFORMATION REQUESTS AT OCTOBER 19 AND 20, 2010 HEARINGS

The Metropolitan Water Reclamation District of Greater Chicago (the "District") hereby files its Responses to the Information Requests made by the Pollution Control Board (the "Board") and parties to this rulemaking at the hearings conducted on October 19 and 20, 2010. At the hearings on those dates, the Board and several parties made requests that the District provide certain information related to the issue of whether disinfection should be required as proposed by the Illinois Environmental Pollution Agency. Attached hereto is a list of those requests, along with the District's itemized Responses to the information requests. For each numbered request, the Response is attached as an Item with the same number. In compiling the requests, the District attempted to group related issues together (such as issues related to nutrients). The particular order of the requests in the list was developed strictly for organizational purposes, and is not meant to convey priority.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

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	INFORMATION REQUEST	**PAGE OF TRANSCRIPT OF REQUEST**
1.	Information on effect of combined sewer overflows and anticipation of pathogens in CAWS	Oct. 19, 2010 Hearing, at 20-21
2.	Analysis of role of hand-washing in reducing risk of illness	Oct. 19, 2010 Hearing, at 193
3.	Update on USEPA recreational WQS activities, including implications for this rulemaking	Oct. 19, 2010 Hearing, at 242
	A Will USEPA address inland waters?	Oct. 20, 2010 Hearing, at 41
	B. In current implementation guidance, what flexibility is there for states in setting WQS for secondary contact waters?	Oct. 20, 2010 Hearing, at 41
	C. What is the USEPA direction in new implementation guidance for secondary contact waters?	Oct. 20, 2010 Hearing, at 41
	D. Will USEPA give states flexibility to consider local conditions and epidemiological studies in setting secondary contact WQS?	Oct. 20, 2010 Hearing, at 41
	E. Slides, webinar materials and other information showing flexibility being considered by USEPA in recreational WQS	Oct. 20, 2010 Hearing, at 43-44
4.	Legal memorandum on whether CAWS qualifies as "protected waters" once new designated uses are set in Subdocket A	Oct. 19, 2010 Hearing, at 245-47
5.	Basis for 15% tax increase claim in pamphlet and expression of likely tax increase in terms of $/$100 EAV	Oct. 20, 2010 Hearing, at 20-21
6.	Expected increase in user fees for tax-exempt organizations and industrial users from disinfection requirements	Oct. 20, 2010 Hearing, at 21

INFORMATION REQUEST		PAGE OF TRANSCRIPT OF REQUEST
7.	Nutrient issues	Oct. 20, 2010 Hearing, at 21-24
	A. Status of Federal and State requirements for MWRD	Oct. 20, 2010 Hearing, at 21-22
	B. Expected compliance costs	Oct. 20, 2010 Hearing, at 21-22
	C. Possible funding sources	Oct. 20, 2010 Hearing, at 22-23
	D. Impact on taxpayers, in dollars per EAV	Oct. 20, 2010 Hearing, at 23
	E. Summary of how increases would change over time if there are continuing costs over the long-term	Oct. 20, 2010 Hearing, at 23
	F. Effect of nutrient removal on effluent bacteria levels	Oct. 20, 2010 Hearing, at 23
8.	Proposed water quality criteria for each of 3 recreational use categories and wet weather use category including specific language as to how the wet weather category could be implemented, and proposed water quality-based effluent limits	Oct. 20, 2010 Hearing, at 44-46
9.	Update economic analysis for MWRD's proposed WQS and effluent limits, with IEPA uses and MWRD uses	Oct. 20, 2010 Hearing, at 48-49
10.	Information to show levels of indicators protective of designated uses	Oct. 20, 2010 Hearing, at 65
11.	Status update on TARP, including timetable for completion of Phases 2 and 3, divided by region	Oct. 20, 2010 Hearing, at 70-72
12.	Information regarding flexibility from USEPA on acceptable rates of illness	Oct. 20, 2010 Hearing, at 80-81
13.	Document regarding agreement on peer review of CHEERS study, if not already in record	Oct. 20, 2010 Hearing, at 118
14.	Studies since October 2009 regarding children and primary contact risks	Oct. 20, 2010 Hearing, at 137-138

ITEM 1

Rainfall and Combined Sewer Overflow Effects on Microbial Water Quality in the Chicago Area Waterways:

A Technical Report

Submitted to the Metropolitan Water Reclamation District of Greater Chicago

December 29, 2010

Rachael M. Jones, PhD
Li Liu, PhD
Samuel Dorevitch, MD, MPH
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Executive Summary

The objectives of this report are to determine (i) if statistical models can predict microbe concentrations in the Chicago Area Waterway System (CAWS) based on information about rainfall and combined sewer overflow (CSO) events; and (ii) to describe the changes in microbe concentrations that are associated with rainfall and CSO events. The availability of a statistical model of this nature is useful to decision-makers because it may identify conditions under which microbial water quality in the CAWS may be acceptable or unacceptable.

Two approaches were taken to the development of the statistical models. The first approach is described as a data-driven approach because it utilizes patterns in the data to identify candidate explanatory variables for inclusion in the statistical model. In general, these types of models can be difficult to interpret for the purpose of decision making because the primary objective of the variable and model selection process is to predict the microbe concentration with the greatest accuracy and precision. This objective leads to statistical models with many variables, such that many combinations of rainfall and CSO event variables can be identified that yield the same predicted water quality. The second approach is described as a conceptually-driven approach because it utilizes a small number of categorical variables based on the timing and threshold of rainfall and CSO events. Conceptually, rainfall and CSO events in closer temporal proximity to water quality assessments are likely to increase microbe concentrations in the CAWS. The variables included in the conceptually-driven models lead to models with more obvious interpretation of the relationship between rainfall and CSO on microbial water quality than the data-driven models.

The final data-driven and conceptually-driven statistical models are "mixed effects models." These models account for the fact that microbe concentrations vary systematically between the monitoring locations in the CAWS. Instead of including separate variables to represent each of the 15 locations at which monitoring occurred, the location is treated as a random effect (a normal distribution with mean zero and standard deviation, σ_l) that allows the model intercept to vary by location. As a result, the intercept describes the average microbe concentration expected in the CAWS, averaged across all locations, under the reference condition. The average microbe concentration expected at a specific location in the CAWS is the sum of the intercept and the random effect for that location. Mathematically, this is expressed in a model with one fixed effect (X) as:

$$y_i = \beta_o + \beta_1 x_{1i} + l_i + \varepsilon_i$$

where y_i is the ith $\log_{10}$ microbe concentration, β_o is the fitted intercept, β_1 is the fitted coefficient for the variable X_1 , l_i is the location random effect for the location of the ith measurement, and ε_i is the random error. From this equation, the mean $\log_{10}$ microbe concentration at the location of the ith measurement, given $x_{1i} = 0$, is $\beta_o + l_i$; and given $x_{1i} \neq 0$, is $\beta_o + l_i + \beta_1 x_{1i}$.

The data-driven models include numerous variables that describe different aspects of CSO events and rainfall, including: time-lag, magnitude, duration and intensity of events; and cumulative magnitude and intensity in specified time-windows, etc. While these models predict microbe concentrations better than the conceptually-driven models, the results are difficult to interpret for the identification of “dry” and “wet” conditions in the CAWS. In addition, the data-driven models for many microbes include variables describing the penultimate CSO event, many of which occurred weeks prior to sample collection. The penultimate CSO event is defined as the next to last CSO event prior to sample collection, where CSO events were distinguished from one another by at least 1 h of no combined sewer overflow within a region of the CAWS. Physically, microbes introduced into the CAWS waters by these CSO events are likely to have passed through the system prior to sample collection. The consistent presence of these variables in the models, however, may indicate that CSO events recharge environmental reservoirs of microbes (e.g. soil and sediment) that are slowly released into CAWS waters; or these variables serve as proxies for as yet unidentified factors.

The conceptually-driven models included one rainfall and one CSO event variable. These variables were treated as factors in the model. The rainfall variable has five levels, reflecting the most recent time-window --- 0-24 h, >24-48 h, >48-72 h, >72-96 h and > 96 h prior to sample collection --- with rainfall in excess of 0.1 inches (or 0.25 inches). The CSO variable has four levels, reflecting the most recent time-window --- 0-24 h, >24-48 h, >48 – 96 h, and > 96 h prior to sample collection, with CSO event duration greater than 1 h. The intercept in the linear effects model represents the CAWS-average mean $\log_{10}$ microbe concentration when no rainfall greater than 0.1 inches (0.25 inches) or CSO duration greater than 1 h has occurred in any time windows within 96 h of sample collection, which is assumed herein to reflect “dry” or baseline conditions.

The conceptually-driven statistical models are summarized in Table 1. The overall model performance is summarized by R^2, which equals the square of the correlation coefficient. Larger values of R^2 indicate better concordance between the measured and fitted $\log_{10}$ microbe concentrations. For all microbes except *Cryptosporidium*, the R^2 values indicated reasonable model performance. For *Cryptosporidium* $R^2 = 0.115$, and indicates that the model does not predict measured concentrations with any fidelity: The only conclusion to draw from this model is that *Cryptosporidium* oocysts concentrations cannot be described with these explanatory variables. For the fecal indicator bacteria *E. coli* and enterococci, about 50% of the variability in microbe concentrations within locations can be accounted for by rainfall and CSO variables.

The conceptually-driven model intercept is described using (i) the CAWS-average intercept (β_o), which reflects the average microbe concentration across all CAWS locations under baseline (dry weather) conditions; and (ii) the 95% range in the intercept when the location effect is taken into consideration ($\beta_o \pm 1.96\ \sigma_l$), which reflects the range of average microbe concentrations expected at specific locations in the CAWS under baseline conditions. The models are fit using the $\log_{10}$ concentration, but values in Table 1 have been transformed to direct concentration units.

The point estimate of dry weather microbe concentrations in Table 1 are considerably lower, in some cases by an order of magnitude, than the mean concentrations of the microbes summarized in Appendix B of the August 31, 2010, CHEERS Final Report. In general, the mean concentrations of the microbes under baseline conditions exhibit substantial variability by location: The 95% range of the intercept with location effect spans 1-2 orders of magnitude. This means that even though microbe concentrations may be relatively low on average in the CAWS under baseline conditions, there are locations where high concentrations are expected.

The time-windows of the categorical CSO and rainfall variables that were found to be significantly associated with microbe concentrations are also listed in Table 1. All coefficients, except that indicated by **, are positive, which mean that rainfall or CSO events above the threshold levels in the specified time-window are associated with an increase in microbe concentrations relative to baseline. For enterococci, the >24-48 h time-window with CSO has a negative coefficient, indicating that CSO in this time window is associated with a decrease in microbe concentrations relative to baseline.

For all microbes except *Giardia*, rainfall in the time-window 0-24 h prior to sample collection is associated with a significant increase in microbe concentrations (Table 1). For all microbes, CSO event in the time-window 0-24 h prior to sample collection is associated with a significant increase in microbe concentrations. These results suggest that a relatively short-time window may be sufficient to distinguish “wet” conditions from baseline conditions in the CAWS. The point estimate of the expected increase in concentration of all microbes was greater for CSO within the prior 24 hours than for rainfall alone within the prior 24 hours.

Given that the 0-24 h time-window is important for the majority of microbes, the CAWS-average microbe concentrations predicted by the conceptually-driven model given rainfall with and without CSO in this time-window are summarized in Table 2. For all microbes, CSO events in the 0-24 h time-window increase microbe concentrations over what is predicted for rainfall alone in the same time-window. Consider, for example, *E. coli* concentrations. As indicated in Table 2, under baseline conditions the mean *E.coli* concentration is 250 CFU/100mL, which increases to 770 CFU/100mL given at least 0.1 inches of rain within 24 h of sample collection, and increases to 2,500 CFU/100mL given rainfall and CSO of at least 1 h within 24 h of sample collection. The random effect of location, summarized by σ_l, is included in the calculations of the 95% range values in Table 2. For all microbes, the 95% ranges are very wide, indicating substantial variability in microbe concentrations at different CAWS locations.

Further model development, however, is required to optimize the selection of time-windows and rainfall and CSO event duration thresholds in those time windows for the determination of water quality management policies in the CAWS. Specifically, given the selection of a microbe and water quality threshold by policy makers, the rainfall and CSO variables can be tailored so as to maximize the sensitivity with which the exceedance of the water quality threshold is predicted.

Table 1. Summary of conceptually-driven statistical models.

		Intercept			Significant Time-Windows	
	R^2	$10^{\beta o}$	95% Range*	Units	CSO >1 h	Rain >0.1in
E. coli	0.497	250	(15, 4080)	CFU /100mL	0-24 h	0-24 h >24-48 h
enterococci	0.454	85	(12,580)	CFU /100mL	0-24h >24-48 h**	0-24 h
somatic coliphage	0.751	87	(1.5, 4900)	PFU /100mL	0-24 h >48-96 h	0-24 h
male-specific coliphages	0.685	2.4	(0.06, 100)	PFU /100mL	0-24 h >48-96 h	0-24 h
***Cryptosporidium* oocyts**	0.115	0.21	(0.07, 0.70)	#oocysts/10L	0-24 h	0-24 h >24-96 h
***Giardia* cysts**	0.552	3.9	(0.05, 290)	#cysts/10L	0-24 h	-

* With location effect, e.g. β_o ±1.96 σ_l taken to the power of 10.
**Indicates negative coefficient.

Table 2. Mean and 95% confidence interval (CI) for CAWS-average microbe concentrations predicted by conceptually-driven models for baseline (dry) conditions compared to rainfall greater than 0.1 inches or CSO duration greater than 1 h in the 24 h prior to sample collection with consideration for location random effect.

			Rain Only (0-24 h)		Rain & CSO (0-24 h)	
	Units	Baseline	Mean	95% Range*	Mean	95% Range
E. coli	CFU/100mL	250	770	48-12,600	2500	150-41,000
enterococci	CFU/100mL	85	180	26-1200	730	110-5020
somatic coliphage	PFU/100mL	87	120	2.2-6970	470	8.4-26,500
male-specific coliphages	PFU/100ml	2.4	3.3	0.08-140	20	0.5-850
***Cryptosporidium* oocyts**	#oocysts/10L	0.21	0.15	0.05-0.45	0.80	0.3-2.4
***Giardia* cysts**	#cysts/10L	3.9	4.0	0.05-300	9.5	0.13-710

* With location effect, e.g. mean $\log_{10}$ value ±1.96 σ_l, taken to the power of 10.

1. Background

This report explores the influence of rainfall and combined sewer overflow events (CSO) on microbial concentrations in the Chicago Area Waterway System (CAWS). Previously in the CAWS, Rijal et al (2009) measured microbe concentrations under dry conditions (at least 72 h since rainfall) and wet conditions (during or immediately after rainfall > 0.5 inches with CSO event), and found that *Giardia* cysts and *Cryptosporidium* oocysts were detected more frequently in wet than dry conditions; and the geometric mean concentration of *E. coli*, enterococci, and fecal coliform were higher in wet than dry conditions. The finding of Rijal et al (2009) reflect the conceptual model that rainfall-related inputs have high microbe density, thereby increasing microbe concentrations in the water body to potentially unacceptable levels.

There is an inherent tension in the development of statistical models to describe the influence of rainfall and CSO events on microbial water quality that arises from an interest in (i) developing the most accurate and precise statistical model, and in (ii) developing a statistical model that can be readily interpreted for decision-making. This is a tension because the optimum statistical model may have too many explanatory variables to be practical, include variables that are difficult to measure, or have a complicated functional form. Decision-making is facilitated when the statistical model includes readily measured explanatory variables that correspond with potential decision criteria, and sensitively indicates exceedence of the critical water quality threshold.

Much water quality research has focused on the latter objective of models for decision-making. The acceptability of microbial water quality is ultimately a policy decision, such that events that trigger unacceptable water quality should be readily identifiable in real-time. An example of such an approach is Nowcasting or Forecasting models, which seek to provide public-service information about recreational water quality (Nevers and Whitman, 2005; Maimone et al 2005; Frick et al, 2008).

The purpose of this technical report is to use linear models to explore the ability of data-driven statistical models, which aim for the optimum statistical prediction of microbial concentrations, and conceptually-driven statistical models, which utilize explanatory variables that can be readily monitored in real time, to explain changes in microbial concentration in the CAWS associated with rainfall and CSO event.

Epidemiologic analysis of adverse health outcomes observed among persons with limited-contact recreation in the CAWS found that rates of acute gastrointestinal illness (AGI) were elevated with respect to rates observed among persons with no water recreation. However, subsequent analyses found no relationship between the concentrations of microbes in the CAWS and increased risk of AGI; but did observe AGI to be associated with CSO events.

2. Data-Driven Models

2.1 Strategy

The strategy was to allow the structure of the data to identify the key rainfall and CSO variables for inclusion in a linear statistical model. The reason for this strategy was the fact that rainfall and CSO can be described in many different ways, and there is no reason a priori to determine which description has the most powerful effect on microbe concentrations. The result of this strategy, however, is that the linear model may not be easily interpreted in the policy context. Linear models that specifically explore the ability of more policy-relevant rainfall and CSO variables to describe changes in microbe concentrations are described subsequently.

2.2 Rainfall and CSO Variables

The CAWS consist of multiple regions. For the analyses here, the distinct regions considered are: North Shore Channel, North Branch Chicago River above and below the North Branch Dam, Main Stem, South Branch, Cal-Sag Channel, Little Calumet River, Grand Calumet River, or Calumet River.

Rainfall events were distinguished from one another by 6 or more hours without measurable rain. The source of the rainfall data is the Illinois State Water Survey, which has gauges throughout Chicago. The rainfall measurement threshold is 0.01 inch per hour. Each region of the CAWS was matched to the nearest gauge(s).

CSO events were distinguished from one another by 1 or more hours without CSO event in a region of the CAWS. The source of CSO data is the Metropolitan Water Reclamation District of Greater Chicago.

Variables defined for this analysis are listed in Table 3. CSO variables include descriptions of the most recent (last) and second to last (penultimate) CSO events, where these events occur in the same region at which the referent water sample was collected, and the penultimate event ends at least 1 h prior to the last event prior to sample collection.

When log-transformed for inclusion in the statistical models, the minimum non-zero value is added to all values of a variable with zero values. For rainfall, this minimum value is 0.01 inches. For time lags, this minimum value is 1 h.

Table 3. Environmental variables for data-driven statistical models

Symbol	Units	Description
Rainfall Variables		
h12.rain	inches	Cumulative rain in the 12 h prior to sample collection
h24.rain	inches	Cumulative rain in the 24 h prior to sample collection
h48.rain	inches	Cumulative rain in the 48 h prior to sample collection
h72.rain	inches	Cumulative rain in the 72 h prior to sample collection
h96.rain	inches	Cumulative rain in the 96 h prior to sample collection
int.h12.rain	inches/hour	Intensity of rain in the 12 h prior to sample collection
int.h24.rain	inches/hour	Intensity of rain in the 24 h prior to sample collection
int.h48.rain	inches/hour	Intensity of rain in the 48 h prior to sample collection
int.h72.rain	inches/hour	Intensity of rain in the 72 h prior to sample collection
int.h96.rain	inches/hour	Intensity of rain in the 96 h prior to sample collection
rain.12.24	inches	Cumulative rain in the > 12–24 h prior to sample collection
rain.24.48	inches	Cumulative rain in the > 24 – 48 h prior to sample collection
rain.48.72	inches	Cumulative rain in the > 48 – 72 h prior to sample collection
rain.72.96	inches	Cumulative rain in the > 72 – 96 h prior to sample collection
last.rain	hours	Hours since the last rainfall
mag.last.rain	inches	Magnitude of the last rain event
dur.last.rain	hours	Duration of the last rain event
Solar Radiation Variables		
cum.sun		Cumulative solar radiation on the day of, but prior to, sample collection
CSO Variables		
last.cso	hours	Hours since the last CSO event
mag.last.cso	10^6 gallons	Magnitude of the last CSO event
dur.last.cso	hours	Duration of the last CSO event
last.cso2	hours	Hours since the penultimate CSO event
mag.last.cso2	10^6 gallons	Magnitude of the penultimate CSO event
dur.last.cso2	hours	Duration of the penultimate CSO event
h.cso	-	Binary variable describing if CSO is ongoing during the hour of sample collection (h.cso = 1)
cso.tot.h.24	hours	Hours in the 24 h prior to sample collection with CSO
cso.tot.h.48	hours	Hours in the 48 h prior to sample collection with CSO
cso.tot.h.96	hours	Hours in the 96 h prior to sample collection with CSO

2.3 Microbe Data

The microbial water quality data were organized for this analysis as follows.

A subset of the indicator microbe data was created for which each row the dataset contained measurements of the four indicator organisms – *E. coli*, enterococci, somatic coliphage, and male-specific coliphages – and the variables listed in Table 3. When coliphages were measured in an hour during which the indicator bacteria were not measured, they were matched to the nearest hour (± 1 h) with indicator bacteria data. Due to the exclusion of *E. coli* enterococci measurements based on laboratory performance, this data set comprised observations of 561unique day-location-hours. This approach, rather than creating separate sets for each microbe, was used to increase comparability across the microbes. The data set includes 230 unique location-day combinations.

A subset of the protozoan pathogen data was created for which each row of the data contained measurements of the two protozoan pathogens – *Cryptosporidium* oocysts and *Giardia* cysts – and the variables listed in Table 3. The protozoan pathogen samples included 368 unique location-day combinations.

Given the relatively large number of unique location-day combinations, and the sampling strategy, which resulted in one protozoan pathogen measurement and 2-3 indicator organism measurements per day, autocorrelation with time is not likely to be a significant problem in the data.

2.4 Data Analysis Methodology

The data analysis was implemented separately for each of the four indicator microbes and the two protozoan pathogens. All models has the functional form:

$$Y = \log_{10} C = f(\mathbf{X}),$$

where Y denotes the predicted variable, which equals the $\log_{10}$ transformed microbe concentration, C; and **X** is a matrix of the explanatory variables (e.g. Table 3).

All analysis was completed in the R statistical programming language (the R Project for Statistical Computing). The methodology used the following steps:

Step 1. Tree Model
Tree models were fit using binary recursive portioning (Crawley, 2007 Ch. 21). In this method, data are successively split such that at each node, the variable (and variable magnitude) that maximally distinguishes the mean microbe concentrations in the two braches is selected. Splitting continues until the microbe concentrations cannot be further separated, or the sample size is too small. The tree models were implemented using the *tree* function, without pruning. The purpose of the tree models was to reduce the number

of explanatory variables to be included in the statistical model: Only variables used in the nodes of the tree model were carried forward into the linear models.

Step 2. Linear Model

Multivariate linear models were fit using the reduced set of explanatory variables identified in the tree models. The linear models were implemented using the *lm* function, and have the functional form:

$$\mathbf{Y} = \beta\mathbf{X} + \varepsilon$$

where **Y** is the vector of $\log_{10}$-transformed microbe concentration measurements, **X** is a matrix of explanatory variables (e.g. rainfall, etc…), ß is the vector of fitted coefficients for the explanatory variables, and ε is the vector of random errors.

If model diagnostics – e.g. plots of standardized residuals versus the rainfall and CSO variables – indicated the need for transformation, the variables were transformed and the linear model fitted again. In all cases, the transformation used was the natural logarithm. Due to differences in microbe concentrations by study locations, the primary purpose of fitting the linear model was to gauge the need for including location. This determination was made by making a box-plot of the standardized residuals from the linear model by locations (a categorical variable): If the median and variance in the standardized residuals varied by location, then location should be included in the model (Zurr, 2009, Ch.5). In all cases, the standardized residuals were found to vary with location.

Step 3. Mixed-Effects Linear Models

Mixed-effects linear models were fit using the reduced set of explanatory variables identified in the tree models as fixed effects, and location as a random effect for the intercept. Alternatively, location could have been used as a fixed effect: This approach, however, means the inclusion of 14 explanatory variables (there are 15 locations). Since our interest is not in the microbe concentration at a specific location, per se, but the influence of rainfall and CSO in the CAW generally, treating location as a random effect is the better approach statistically. Any variables identified in the multivariate linear models as needing transformation, were log-transformed for use in the mixed-effects models.

Mixed-effects linear model is implemented such that location is a random effect on the intercept, and results in location-specific intercepts. The model has following functional form:

$$\mathbf{Y} = \beta\mathbf{X} + l + \varepsilon$$

where **Y** is the vector of $\log_{10}$-transformed microbe concentrations, **X** is a matrix of explanatory variables (fixed effects), β is the vector of fitted coefficients for the fixed effects, l is the location random effect (e.g., $l \sim N(0, \sigma_l)$), and ε is the vector of random errors (e.g. $\varepsilon \sim N(0,\sigma)$).

The intercept of the linear mixed effects model (e.g. β_o) is the average $\log_{10}$ microbe concentration predicted in the CAWS; while the random effect of location describes the change in mean concentration at different locations. The magnitude of the random effect is summarized by the standard deviation, σ_l , but a specific random effect coefficient is also calculated for each location, l_i. As a result, the mean $\log_{10}$ microbe concentration at a specific location *i* equals $\beta_o + l_i$; and the general range of mean $\log_{10}$ microbe concentration can be summarized as the sum of β_o and the 95% confidence range for the location random effect, $\beta_o \pm 1.96 \times \sigma_l$.

The mixed-effects linear models were fit using the *lme* function, by the maximum likelihood method. A backward-step model reduction was used, with terms removed based on the coefficient *p*-value, until all terms had $p \leq 0.10$. The threshold $p = 0.10$ was used instead of $p = 0.05$ because the primary interest is in the accuracy of predictions and not statistical efficiency. The reduced models were compared using the *anova* function, and the best model selected based on the minimum AIC, given a *p*-value in the ANOVA table $p > 0.05$ when tested against the full model. The best model was fitted again using the *lme* function by the REML method.

The fit of the best mixed-effects model was gauged graphically by comparison of (i) the standardized residuals and the fitted values, and (ii) the measured values and the fitted values. Model performance was summarized by the coefficient of determination (R^2), equal to the square of the Pearson's product-moment correlation coefficient. Inability of the model to explain the observed variability suggested the addition of interaction terms.

Step 4. Mixed-Effects Linear Models with Interaction Terms

Rainfall increases the likelihood and magnitude of CSO events, which suggests that interactions between rainfall and CSO variables may be appropriate for inclusion the mixed-effects linear models.

Only two-way interactions between rainfall variables and CSO variables were tested. If the model included two or more rainfall (or CSO) variables, interactions between the multiple rainfall (or CSO) variables were not tested. Interactions with cumulative solar radiation were not tested. When the number of rainfall and CSO variables were small, all interactions were added simultaneously to the model and backward-step model reduction proceeded as previously described. When this was not possible due to the large number of variables, separate models were fit that included interactions between one rainfall variable and all CSO variables. Any interactions identified in these models with coefficient $p < 0.20$ were included in the "full" model.

In either case, model reduction proceed by the backward-step method with criterion $p \leq 0.10$, where models were fit using the *lme* function and the maximum likelihood method. The reduced models were compared using the *anova* function, and the best model selected based on the minimum AIC, given an ANOVA *p*-value of $p > 0.05$ when tested against the full model. The best model was fitted again using the *lme* function by the REML method.

The fit of the best mixed-effects model was gauged graphically by comparison of (i) the standardized residuals and the fitted values, and (ii) the measured values and the fitted values.

Model performance was summarized by the coefficient of determination (R^2), equal to the square of the Pearson’s product-moment correlation coefficient.

2.5 *E. Coli* Results

The tree model includes 13 terminal nodes, and six unique variables. The rainfall variables are: last.rain, and h96.rain. The CSO variables are: last.cso, last.cso2, cso.tot.h.48, and mag.last.cso.

The standardized residuals, from linear models with untransformed and log-transformed explanatory variables, varied in their distribution by location, indicating the need for the mixed-effects linear model.

The final mixed-effects model includes all six variables and five interaction terms. All variables were log-transformed to improve the distribution of standardized residuals against the explanatory variables. The final model fit by REML is presented in Table 4. Note that the intercept cannot be interpreted as the *E. coli* concentration under “dry” conditions because the explanatory variables contain information on both the magnitude and time-lag since rainfall or CSO event.

Overall fit of the model is reasonable, with Pearson’s correlation coefficient equal to 0.724, which gives $R^2 = 0.524$. Variance in the standardized residuals, however, decreases with increasing fitted values (data not shown), indicating that the model does not fully explain the observed variability in *E. coli* concentrations. Figure 1 illustrates that the model tends to over-estimate low measured values, and under-estimate high measured values.

Table 4. Data-driven linear mixed effects model of $\log_{10}$ *E. coli* concentration ($\log_{10}$ CFU/100mL) in the CAWS.

Variable	Coefficient
Intercept	3.84
log(last.cso2)	-0.195
log(last.rain+1)	-0.403
log(last.cso+1)	0.028
log(mag.last.cso)	0.005
log(h96.rain+0.01)	0.372
log(cso.tot.h.48+1)	-0.015
log(last.rain+1)×log(last.cso+1)	0.084
log(last.rain+1) × log(mag.last.cso)	-0.025
log(last.cso+1) × log(h96.rain+0.01)	0.047
log(mag.last.cso) × log(h96.rain+0.01)	-0.023
log(h96.rain+0.01) × log(cso.tot.h.48 + 0.01)	0.216
Random Effect Standard Deviation	0.553

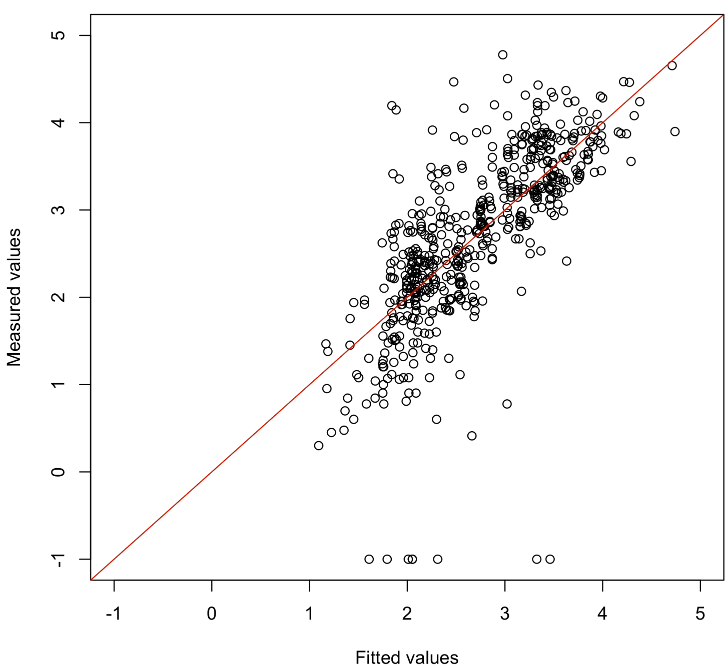

Figure 1. Comparison of measured and fitted $\log_{10}$ *E. coli* by mixed-effects linear model.

2.6 Enterococci Results

The tree model for enterococci includes 16 terminal nodes, and 12 explanatory variables. The rain variables include: h24.rain, h72.rain, last.rain, mag.last.rain, and dur.last.rain. The CSO variables include: cso.tot.h.24, mag.last.cso, mag.last.cso2, dur.last.cso2, last.cso and last.cso2. In addition, the cum.sun variable is included.

The standardized residuals from linear models with untransformed and log-transformed explanatory variables (except cum.sun) were not uniformly distributed across locations. As a result, location was included as a random effect.

In the mixed-effects model, all variables except cum.sun were log-transformed. The mixed-effects model without interaction terms had randomly distributed standardized residuals against the fitted values (data not shown). As a result, interaction terms were not tested. The backward-step model selection process yielded the final model, fit by REML, presented in Table 5. Note that the intercept cannot be interpreted as the enterococci concentration under "dry" conditions because the explanatory variables contain information on both the magnitude and time-lag since rainfall or CSO event.

The overall performance of the model was good (Figure 2), with no evidence of systematic over- or under-prediction of the $\log_{10}$ enterococci concentrations. The Pearson's correlation coefficient equals 0.693, giving $R^2 = 0.480$.

Table 5. Data-driven linear mixed effects model of $\log_{10}$ enterococci concentration ($\log_{10}$ CFU/100 mL) in the CAWS.

Variable	Coefficient
Intercept	2.88
log(h72.rain+0.01)	0.044
log(h24.rain+0.01)	0.068
log(mag.last.rain)	-0.058
log(mag.last.cso)	-0.024
log(mag.last.cso2)	0.040
log(dur.last.cso2)	-0.079
cum.sun	-0.025
log(cso.tot.h.24+1)	0.165
Random Effect Standard Deviation	0.458

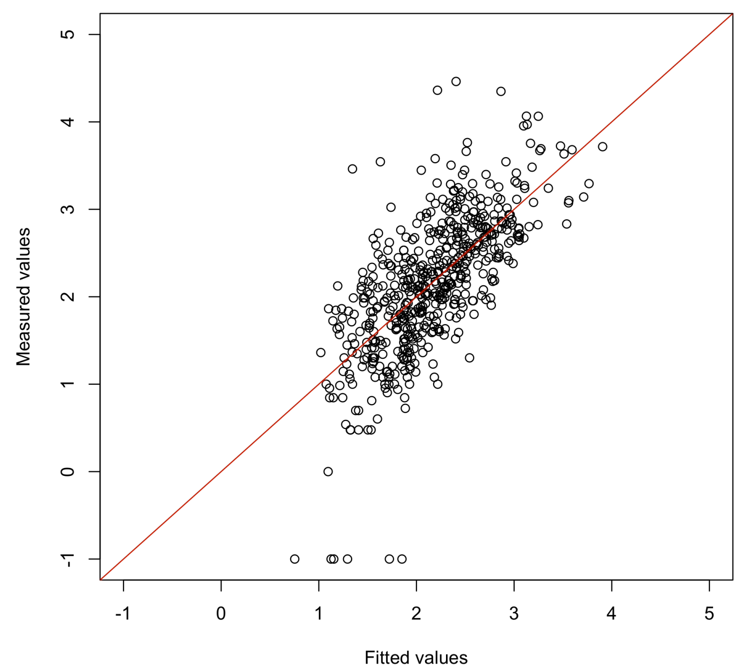

Figure 2. Comparison of measured and fitted $\log_{10}$ enterococci concentration by mixed-effects linear model.

2.7 Somatic Coliphage Results

The tree model includes eight terminal nodes, and four unique variables. The rain variables are: h72.rain and h96.rain. The CSO variables are: last.cso2 and mag.last.cso2.

A linear model was fit, and the distribution of the standardized residuals against the explanatory variables indicated the need for log-transformation of the explanatory variables. After transformation, the standardized residuals of the linear model were not uniformly distributed across locations. As a result, location was included as a random effect.

The final mixed-effects model includes all four variables and three interaction terms. All variables were log-transformed to improve the distribution of standardized residuals against the explanatory variables. The final model fit by REML is presented in Table 6. Note that the intercept cannot be interpreted as the somatic coliphage concentration under "dry" conditions because the explanatory variables contain information on both the magnitude and time-lag since rainfall or CSO event.

The standardized residuals show more positive values of large magnitude for small fitted values (data not shown). The concordance of measured and fitted $\log_{10}$ somatic coliphage concentrations, however, is good (Figure 3). The Pearson's correlation coefficient between measured and fitted $\log_{10}$ somatic coliphage concentrations equals 0.876, giving $R^2 = 0.768$.

Table 6. Data-driven linear mixed effects model for $\log_{10}$ somatic coliphage concentration ($\log_{10}$ PFU/100 mL) in the CAWS.

Variable	Coefficient
Intercept	2.59
log(last.cso2)	-0.075
log(h96.rain+0.01)	-0.297
log(h72.rain+0.01)	0.331
log(mag.last.cso2)	0.039
log(last.cso2) × log(h96.rain+0.01)	0.054
log(last.cso2) × log(h72.rain+0.01)	-0.041
log(h96.rain+0.01) × log(mag.last.cso2)	-0.001
Random Effect Standard Deviation	0.833

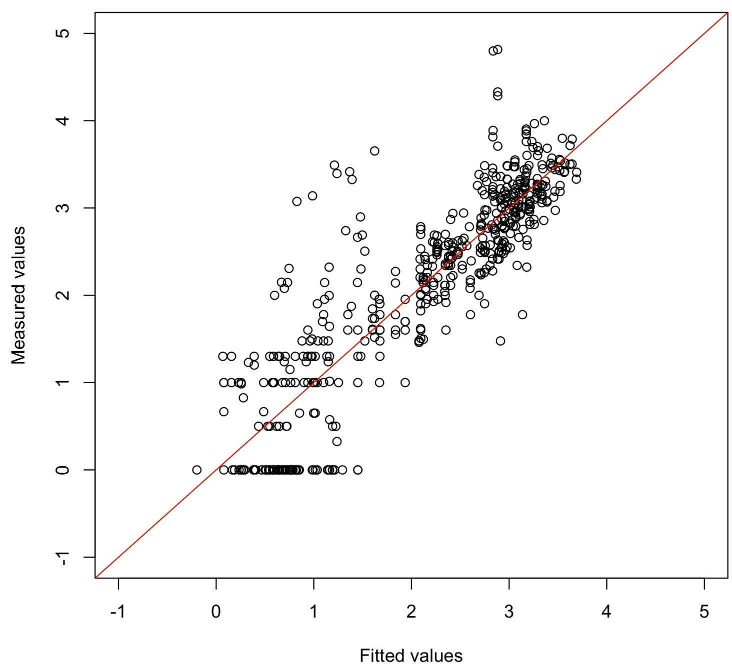

Figure 3. Comparison of measured and fitted $\log_{10}$ somatic coliphage by mixed-effects linear model.

2.8 Male-Specific Coliphages Results

The tree model includes eight terminal nodes and six unique variables. The rain variables are: last.rain, dur.last.rain, and h72.rain. The CSO variables are: last.cso, last.cso2, and dur.last.cso.

A linear model was fit with the six variables. Standardized residuals plotted against the fitted values indicated the need for log-transformation of the explanatory variables. The linear model with log-transformed explanatory variables had non-uniform distributions of standardized residuals by location. As a result, location was included as random variable.

The mixed-effects linear model contains the six variables and three interaction terms. The final model fit by REML is presented in Table 7. Note that the intercept cannot be interpreted as the male-specific coliphages concentration under "dry" conditions because the explanatory variables contain information on both the magnitude and time-lag since rainfall or CSO event.

The standardized residuals plotted were more likely to be positive and of large magnitude for smaller fitted values (data not shown). Bias is evident for small fitted values in Figure 4. The Pearson's correlation coefficient between measured and fitted $\log_{10}$ male-specific coliphages concentrations is 0.843, giving $R^2 = 0.711$.

Table 7. Data-driven linear mixed effect model of $\log_{10}$ male-specific coliphages concentration ($\log_{10}$ PFU/100mL) in the CAWS.

Variable	Coefficient
Intercept	1.18
log(last.cso2)	0.088
log(last.cso+1)	-0.236
log(dur.last.cso)	0.102
log(h72.rain+0.01)	-0.183
log(dur.last.rain)	0.068
log(last.rain+1)	-0.273
log(last.cso) × log(h72.rain+0.01)	0.026
log(dur.last.cso) × log(h72.rain+0.01)	0.039
log(last.cso) × log(last.rain)	0.038
Random Effect Standard Deviation	0.936

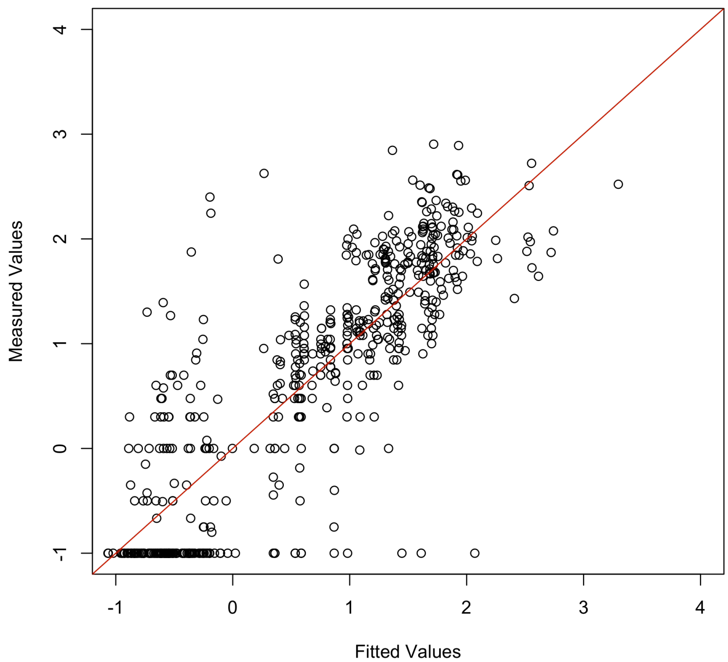

Figure 4. Comparison of measured and fitted $\log_{10}$ male-specific coliphages concentration by mixed-effects linear model.

2.9 *Cryptosporidium* Oocysts Results

The tree model has 17 terminal nodes and 11 variables. The rainfall variables are: h12.rain, h96.rain, rain.24.48, rain.72.96, and mag.last.rain. The CSO variables are: dur.last.cso, last.cso, mag.last.cso, last.cso2, mag.last.cso2, and dur.last.cso2.

The distributions of standardized residuals from the linear models, both the untransformed and log-transformed explanatory variables, varied by location. As a result, location was included as a random effect.

Diagnostics of the mixed-effects model indicated that the model did not adequately explain the observed variance in *Cryptosporidium* oocysts concentrations. Due to the large number of explanatory variables identified in the tree model, interactions were tested for each rainfall variable in turn and interactions with coefficient $p \leq 0.20$ were included for final model selection. All variables except cum.sun were log-transformed.

The interaction terms identified for inclusion are: h96.rain × dur.last.cso, h96.rain × dur.last.cso2, h96.rain × mag.last.cso2, mag.last.rain × dur.last.cso2, mag.last.rain × mag.last.cso2, mag.last.rain × last.cso2, and mag.last.rain × mag.last.cso, h12.rain ×

last.rain, rain.72.96 × last.cso, rain.72.96× last.cso2, rain.24.48× dur.last.cso, rain.24.28 × dur.last.cso2, rain.24.48 × last.cso2, rain.24.48 × mag.last.cso2.

The backward-step model selection process yielded the model presented in Table 8. Note that the intercept cannot be interpreted as the *Cryptosporidium* oocysts concentration under “dry” conditions because the explanatory variables contain information on both the magnitude and time-lag since rainfall or CSO event. The overall performance of the linear mixed-effects model is relatively poor. The Pearson’s correlation coefficient for the measured and fitted $\log_{10}$ *Cryptosporidium* oocysts concentrations is 0.571, giving $R^2 = 0.327$. The standardized residuals decrease with increasing fitted values (data not shown), which is evident in Figure 5 by the systematic under-prediction of the measured values for high fitted values.

Table 8. Data-driven linear mixed effects model of $\log_{10}$ *Cryptosporidium* oocysts concentration ($\log_{10}$ #oocysts/10L) in the CAWS.

Variable	Coefficient
Intercept	-1.46
log(h12.rain+0.01)	-0.154
log(h96.rain+0.01)	0.058
log(mag.last.rain)	0.148
log(dur.last.cso)	0.117
log(dur.last.cso2)	0.205
log(last.cso+1)	-0.171
log(last.cso2)	0.168
log(mag.last.cso)	-0.035
log(mag.last.cso2)	-0.076
log(rain.24.48+0.01)	0.072
log(h96.rain+0.01) × log(dur.last.cso2)	0.055
log(h96.rain+0.01) × log(mag.last.cso2)	-0.036
log(mag.last.rain) × log(mag.last.cso2)	-0.046
log(mag.last.rain) × log(mag.last.cso)	0.037
log(mag.last.rain) × log(last.cso2)	-0.052
log(mag.last.rain) × log(dur.last.cso2)	0.117
log(dur.last.cso) × log(rain.24.48+0.01)	-0.028
Random Effect Standard Deviation	0.509

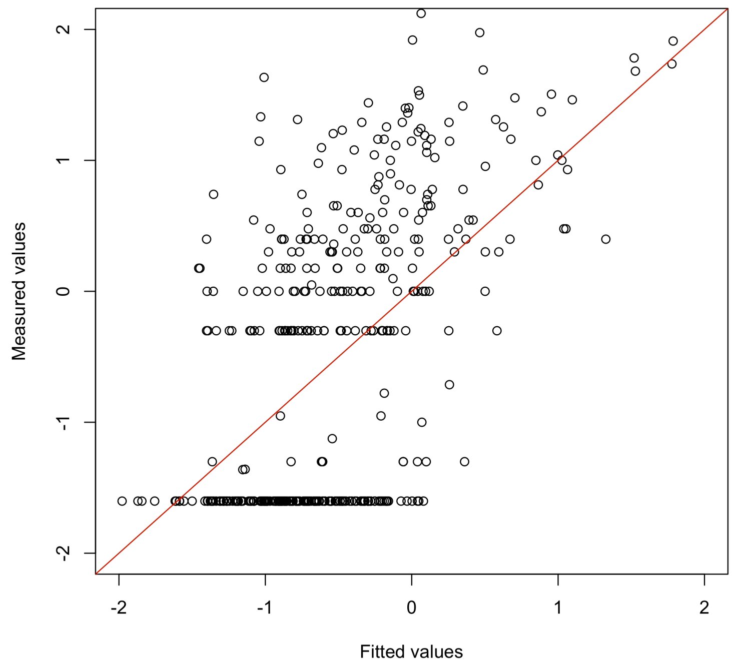

Figure 5. Comparison of measured and fitted $\log_{10}$ *Cryptosporidium* oocysts concentrations by mixed-effects linear model.

2.10 *Giardia* Cyst Results

The tree model has nine terminal nodes and six variables. The rain variables are: last.rain, mag.last.rain, and h24.rain. The CSO variables are: last.cso and last.cso2. The variable cum.sun is also included.

The distributions of standardized residuals from the linear models, both the untransformed and log-transformed explanatory variables, varied by location. As a result, location was included as a random variable.

The residuals from the mixed-effects model with log-transformed rainfall and CSO variables did not show a strong systematic pattern. Therefore, interaction terms were not tested. The final model, fit by REML after backward-step model selection, is presented in Table 9. Note that the intercept cannot be interpreted as the *Giardia* cyst concentration under "dry" conditions because the explanatory variables contain information on both the magnitude and time-lag since rainfall or CSO event. The fitted values show good concordance with the measured values (Figure 6). The Pearson's correlation coefficient for measured versus fitted $\log_{10}$ *Giardia* cyst concentrations equals 0.750, which gives $R^2 = 0.562$.

Table 9. Data-driven linear mixed effects model of $\log_{10}$ *Giardia* cyst concentrations ($\log_{10}$ #cysts/10L) in the CAWS.

Variable	Coefficient
Intercept	1.11
log(last.cso+1)	-0.086
log(mag.last.rain)	0.038
Random Effect Standard Deviation	0.918

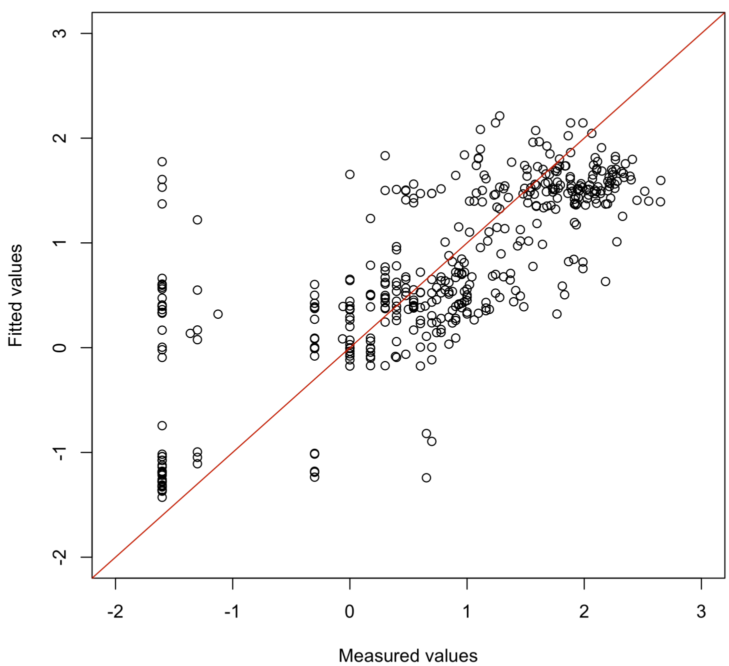

Figure 6. Comparison of measured and fitted *Giardia* cyst concentrations ($\log_{10}$ #cysts/10L) in final mixed-effects model.

3. Conceptually-driven Models

3.1 Strategy

The strategy taken here is to identify categorical variables that describe rainfall and CSO in ways that are readily measured, and use these variables in simple statistical models to predict microbe concentrations. These models will need to be tailored for specific policy objectives, but the results presented serve to illustrate the concept and evaluate a small set of potential explanatory variables. Future work, for example, may be to tailor the sensitivity of the model to a threshold microbe concentration by modifying the definition of the categorical explanatory variables. For example, if a threshold microbe concentration is identified (C*), then the threshold in the categorical variables ($X > \tau$) included the models may be adjusted to meet the objective of $\min_{X > \tau}(C - C^*)$. Alternatively, logistic models could be implemented to determine the probability of exceeding the threshold microbe concentration, e.g. $\Pr(C > C^*)$.

3.2 Rainfall and CSO Variables

Previous investigators have focused on the changes in microbe concentrations under wet weather conditions relative to dry weather conditions. Generally, these analyses have defined wet conditions by:

i) cumulative rainfall in some recent time period (Frick et al 2008; Nevers and Whitman 2005; Wong et al 2009; Eleria and Vogel 2005; Schets et al 2008; Mallin et al 2009; Wilkes et al 2009),
ii) cumulative rainfall above a threshold in some recent time period (Astrom et al 2009), and/or
iii) combined sewer overflow events in some recent time period (Rijal et al 2009).

Based on previous studies, and the objectives of the conceptually-driven statistical models, a series of categorical variables were defined based on the magnitude and timing of rainfall and CSO. Essentially these variables (Table 10) describe the most recent time-window with rainfall over 0.1 inches or 0.25 in, or CSO duration greater than 1 h.

3.3 Microbe Data

The same microbe data were used in the analysis of conceptually-driven statistical models as were used in the data-driven statistical models.

Table 10. Categorical rainfall and CSO variables for development of conceptually-driven models

Variable	Description	
rain.cat0.1in	Categorical Variable (factor)	
	=4	Rainfall in excess of 0.1 inches in the 24 h prior to sample collection
	=3	Rainfall in excess of 0.1 inches in the >24-48 h prior to sample collection, but not within 24 hours of sample collection.
	=2	Rainfall in excess of 0.1 inches in the >48-72 h prior to sample collection, but not within 48 h of sample collection
	=1	Rainfall in excess of 0.1 inches in the >72-96 h prior to sample collection, but not within 72 h of sample collection
	=0	No rainfall in excess of 0.1 inches any 24 h period within 96 of sample collection (assumed to be rainfall-free conditions)
rain.cat0.25in	Categorical Variable (factor)	
	=4	Rainfall in excess of 0.25 inches in the 24 h prior to sample collection
	=3	Rainfall in excess of 0.25 inches in the >24-48 h prior to sample collection, but not within 24 h of sample collection.
	=2	Rainfall in excess of 0.25 inches in the >48-72 h prior to sample collection, but not within 48 h of sample collection
	=1	Rainfall in excess of 0.25 inches in the >72-96 h prior to sample collection, but not within 72 h of sample collection
	=0	No rainfall in excess of 0.25 inches any 24 h period within 96 of sample collection (assumed to be rainfall-free conditions)
cso.cat.1h	Categorical Variable (factor)	
	=3	CSO in duration of 1 h or more in the 24 h prior to sample collection
	=2	CSO in duration of 1 h or more in the >24-48 h prior to sample collection, but not within 24 h of sample collection
	=1	CSO in duration of 1 h or more in the >48-96 h prior to sample collection, but not within 48 h of sample collection
	=0	No CSO in duration of 1 h or more in any 24 h period within 96 of sample collection (assumed to be CSO-free conditions)

3.4 Data Analysis Methodology

Linear mixed-effects models, with location as a random effect, were fitted to predict the $\log_{10}$ microbe concentration as a function of rainfall and CSO variables (Table 10) using the *lme* function in the R statistical programming language (The R Project for Statistical Computing). Due to the sample size, it was not possible to include interaction terms. All models were fit by REML since a model selection process was not used.

The variables were treated as factors, rather than continuous variables to highlight which time windows of rainfall and CSO most greatly influence microbe concentration in the CAWS.

3. 5 *E. coli* Results

Linear mixed effects were fit with two rainfall thresholds – 0.1 inches and 0.25 inches– for each 24 h period. The coefficients of the fixed effects are summarized in Table 11. Scatter plots of the measured versus fitted $\log_{10}$ *E. coli* concentrations (Figure 7) show that both models perform similarly. The location random effect has standard deviation 0.618 and 0.602 $\log_{10}$ *E. coli* CFU/100mL for the 0.1 inches and 0.25 inches rainfall threshold models, respectively.

For the rainfall 0.1 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ *E. coli* concentrations is 0.705, giving $R^2 = 0.497$.

This model has intercept 2.40, indicating that under the baseline (e.g. "dry") conditions (e.g. rainfall less than 0.1 inches and less than 1 h CSO per time-window), the mean *E. coli* concentration in the CAWS is 250 CFU/100 mL ($10^{2.40}$). Since location is a random effect for the intercept, the mean *E. coli* concentration at a specific location may be higher or lower than 250 CFU/100mL. More specifically, when the location random effect is included, the 95% confidence interval for the intercept is defined $2.40 \pm 1.96 \times 0.618$ $\log_{10}$ *E. coli* CFU/100 mL. This translates into a range of 1.19-3.61 $\log_{10}$ CFU/100mL or 15-4080 CFU/100mL.

The model indicates that rainfall within 48 h of sample collection significantly increases the *E. coli* concentration, as does CSO within 24 h of sample collection. The model indicates that when rainfall exceeds 0.1 inches and CSO duration exceeds 1 h in the 24 h prior to sample collection, the mean *E. coli* concentration in the CAWS will be 2500 CFU/100 mL ($10^{(2.40+0.488+0.513)}$). Including the location random effect, the 95% confidence range of *E. coli* concentrations is 150-41,000 CFU/100mL.

For the rainfall 0.25 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ *E. coli* concentrations is 0.695, giving $R^2 = 0.482$.

The model has intercept 2.45, indicating that under baseline conditions, the mean *E. coli* concentration in the CAWS is 280 CFU/100mL. Incorporating the random effect of location, the 95% confidence interval for the intercept is defined $2.45 \pm 1.96 \times 0.602$ $\log_{10}$ *E. coli* CFU/100 ml. This translates to a range of 19-4,270 CFU/100 mL. These numbers are slightly higher than when the rainfall threshold is 0.1 inches, which is to be expected since the baseline conditions include the potential for additional rainfall (e.g. up to 0.25 inches per 24 h window).

As with the lower rainfall threshold, the model indicates than rainfall in the 48 h prior to sample collection and CSO in the 24 h prior to sample collection significantly increases the average *E. coli* concentration in the CAWS.

Table 11. Linear mixed effects models predicting the $\log_{10}$ *E. coli* concentration ($\log_{10}$ CFU/100 mL) in the CAWS.

	Coefficients	
Variable	**Rain ≥ 0.1 in**	**Rain ≥ 0.25 in**
Intercept	2.40*	2.45*
Rain Category 4 (<24 h)	0.488*	0.399*
Rain Category 3 (>24-48 h)	0.265*	0.262*
Rain Category 2 (>48-72 h)	0.018	0.055
Rain Category 1 (>72-96 h)	0.139	0.097
CSO Category 3 (<24 h)	0.513*	0.518*
CSO Category 2 (>24-48 h)	0.143	0.081
CSO Category 1 (>48-96 h)	-0.224	-0.171
Random Effect Standard Deviation	0.618	0.602

* $p < 0.05$

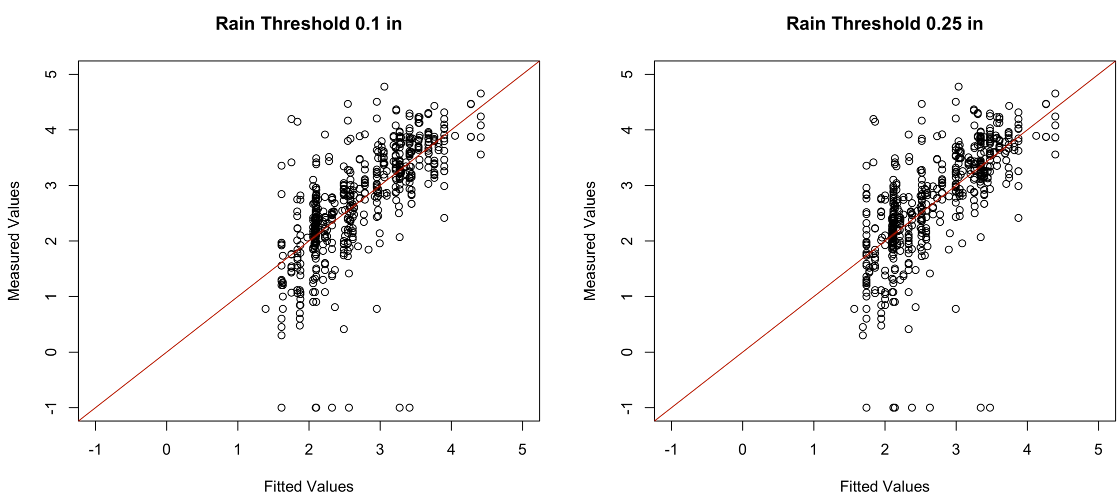

Figure 7. Measured versus fitted $\log_{10}$ *E. coli* concentrations ($\log_{10}$ CFU/100mL) for the linear mixed effects models.

3.6 Enterococci Results

Linear mixed effects were fit with two rainfall thresholds – 0.1 inches and 0.25 inches– for each 24 h period. The coefficients of the fixed effects are summarized in Table 12. Scatter plots of the measured versus fitted $\log_{10}$ enterococci concentrations (Figure 8) show that both models perform similarly. The location random effect has standard deviation 0.427 and 0.437 $\log_{10}$ enterococci CFU/100mL for the 0.1 inches and 0.25 inches rainfall threshold models, respectively. These standard deviations are smaller than that estimated for *E.coli*, indicating that the enterococci variation by location in the CAWS is smaller than the *E.coli* variation by location.

For the rainfall 0.1 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ enterococci concentrations is 0.674, giving $R^2 = 0.454$.

This model has intercept 1.93, indicating that baseline (e.g. "dry") conditions (e.g. rainfall less than 0.1 inches and less than 1 h CSO per time-window), the mean enterococci concentration in the CAWS is 85 CFU/100 mL ($10^{1.93}$). Since location is a random effect for the intercept, the mean enterococci concentration at a specific location may be higher or lower than 85 CFU/100mL. More specifically, if the random effect is considered, the 95% confidence interval for the intercept is defined $1.93 \pm 1.96 \times 0.427$ $\log_{10}$ CFU/100 mL. This translates into a range of 1.09-2.77 $\log_{10}$ CFU/100 mL, or 12-580 CFU/100 mL.

The model indicates that rainfall within 24 h of sample collection significantly increases the enterococci concentration. The model also indicates that the effect of CSO can be long, though the coefficient for CSO in the time-window >24-48 h has a negative coefficient. The model indicates than when rainfall exceeds 0.1 inches and CSO duration exceeds 1 h in the 24 h prior to sample collection, the mean enterococci concentration in the CAWS will be 730 CFU/100 mL ($10^{(1.93+0.329+0.605)}$). Including the location effect, the 95% confidence range around this estimate is 110-5,020 CFU/100mL.

For the rainfall 0.25 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ enterococci concentrations is 0.668, giving $R^2 = 0.446$.

The model has intercept 1.96, indicating that under the baseline conditions the mean enterococci concentration in the CAWS is 90 CFU/100mL. This number is slightly higher than when the rainfall threshold is 0.1 inches, which is to be expected since the baseline conditions include the potential for additional rainfall (e.g. up to 0.25 inches per 24 h window). When the location random effect is included in the model, the 95% confidence interval is defined $1.96 \pm 1.96 \times 0.437$ $\log_{10}$ CFU/100mL. This translates into a range of 13-660 CFU/100mL.

As with the lower rainfall threshold, the model indicates than rainfall in the 24 h prior to sample collection and CSO over all time-windows significantly influence enterococci concentrations.

Table 12. Linear mixed effects models for $\log_{10}$ enterococci concentrations ($\log_{10}$ CFU/100 mL) in the CAWS.

Variable	Coefficients Rain ≥ 0.1 in	Rain ≥ 0.25 in
Intercept	1.93*	1.96*
Rain Category 4 (<24 h)	0.329*	0.319*
Rain Category 3 (>24-48 h)	0.147	0.067*
Rain Category 2 (>48-72 h)	-0.069	-0.039
Rain Category 1 (>72-96 h)	-0.138	-0.176
CSO Category 3 (<24 h)	0.605*	0.573*
CSO Category 2 (>24-48 h)	-0.435*	-0.413*
CSO Category 1 (>48-96 h)	0.382*	0.418*
Random Effect Standard Deviation	0.427	0.437

*$p < 0.05$

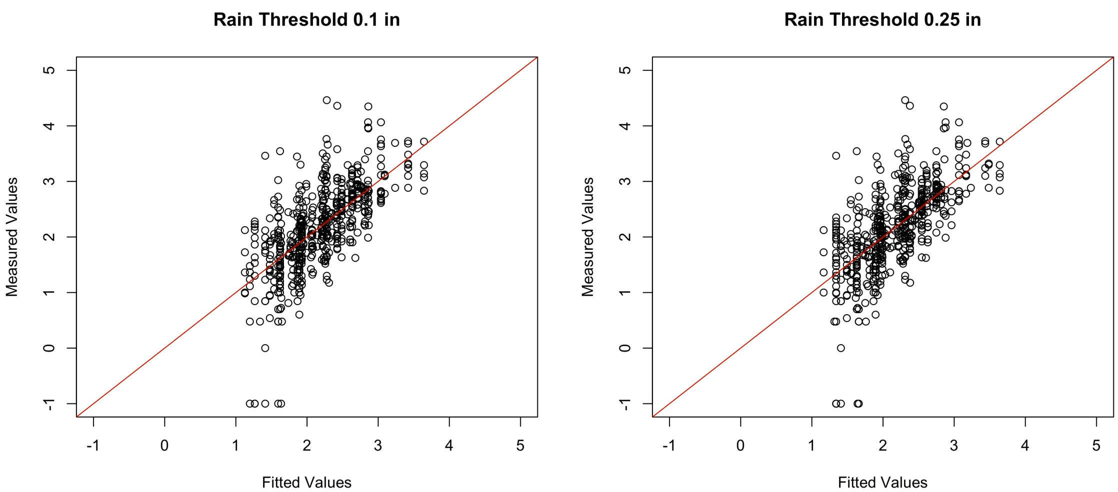

Figure 8. Measured versus fitted $\log_{10}$ enterococci concentrations ($\log_{10}$ CFU/100 mL) from linear mixed effects models.

3.7 Somatic Coliphage Results

Linear mixed effects were fit with two rainfall thresholds – 0.1 inches and 0.25 inches– for each 24 h period. The coefficients of the fixed effects are summarized in Table 13. Scatter plots of the measured versus fitted $\log_{10}$ somatic coliphage concentrations (Figure 9) show that both models perform similarly. The location random effect has standard deviation 0.893 and 0.894 $\log_{10}$ somatic coliphage PFU/100mL for the 0.1 inches and 0.25 inches rainfall threshold models, respectively. These standard deviations are larger than those estimated for the indicator bacteria, indicating that somatic coliphage concentrations vary widely by location in the CAWS.

For the rainfall 0.1 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ somatic coliphage concentrations is 0.867, giving R^2 = 0.751.

This model has intercept 1.94, indicating that under baseline (e.g. "dry") conditions (e.g. rainfall less than 0.1 inches and less than 1 h CSO per time-window), the mean somatic coliphage concentration in the CAWS is 87 PFU/100 mL ($10^{1.93}$). Since location is a random effect for the intercept, the mean somatic coliphage concentration at a specific location may be higher or lower than 87 PFU/100mL. More specifically, when the random effect is included, the 95% confidence interval for the intercept is defined as 1.94 $\pm$ 1.96 $\times$ 0.893 $\log_{10}$ PFU/100mL. This translates into a range of 0.190-3.69 $\log_{10}$ PFU/100mL or 1.5-4900 PFU/100mL.

The model indicates that rainfall within 24 h of sample collection significantly increases the somatic coliphage concentration. CSO in the 0-24 h and >48-96 h time window also significantly increase somatic coliphage concentrations. The model indicates than when rainfall exceeds 0.1 inches and CSO duration exceeds 1 h in the 24 h prior to sample collection, the mean somatic coliphage concentration in the CAWS will be 470 PFU/100 mL ($10^{(1.94+0.153+0.580)}$). Including the random effect of location, the 95% confidence range around the mean somatic coliphage concentration is 8.4-26,500 PFU/100mL. The effect of CSO in this time-window on somatic coliphage concentration is greater than the effect of rainfall.

For model with the rainfall threshold 0.25, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ somatic coliphage concentrations 0.868, giving R^2 = 0.754.

The model has intercept 1.93, indicating that under baseline conditions the mean somatic coliphage concentration in the CAWS is 85 PFU/100mL. Including the random effect of location, the 95% confidence interval for the intercept is defined by 1.93 $\pm$ 1.96 $\times$ 0.894 $\log_{10}$ PFU/100mL. This translates into a range of 1.51-4800 PFU/100 mL.

As with the lower rainfall threshold model, the model indicates than rainfall in the 24 h prior to sample collection and CSO in the 0-24 h and >48-96 h time-windows significantly increase somatic coliphage concentrations. Again, the effect of CSO is greater than the effect of rainfall.

Table 13. Linear mixed effects models for $\log_{10}$ somatic coliphage concentrations ($\log_{10}$ PFU/100mL) in the CAWS.

Variable	Coefficients	
	Rain ≥ 0.1 in	**Rain ≥ 0.25 in**
Intercept	1.94*	1.93*
Rain Category 4 (<24 h)	0.153*	0.248*
Rain Category 3 (>24-48 h)	0.022	0.056
Rain Category 2 (>48-72 h)	0.059	-0.048
Rain Category 1 (>72-96 h)	-0.094	-0.078
CSO Category 3 (<24 h)	0.580*	0.494*
CSO Category 2 (>24-48 h)	0.053	0.024
CSO Category 1 (>48-96 h)	0.405*	0.430*
Random Effect Standard Deviation	0.893	0.894

*$p < 0.05$

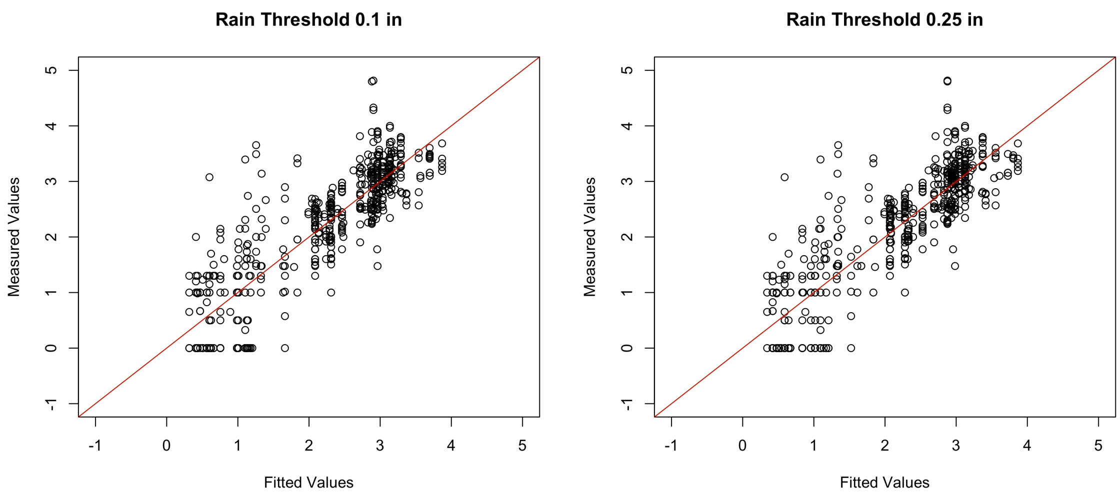

Figure 9. Measured versus fitted $\log_{10}$ somatic coliphage concentrations ($\log_{10}$ PFU/100mL) in linear mixed effects models.

3.8 Male-Specific Coliphages Results

Linear mixed effects were fit with two rainfall thresholds – 0.1 inches and 0.25 inches– for each 24 h period. The coefficients of the fixed effects are summarized in Table 14.

Scatter plots of the measured versus fitted $\log_{10}$ male-specific coliphages concentrations (Figure 10) show that both models perform similarly. For the rainfall 0.1 inches threshold, the location random effect has standard deviation 0.828. For the rainfall 0.25 inches threshold, the location random effect has standard deviation 0.825. These standard deviations are similar to those for somatic coliphage.

For rainfall threshold 0.1 inches model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ male-specific coliphages concentrations is 0.827, giving R^2 = 0.685.

This model has intercept 0.388, but this is only statistically significantly different from zero at the $p = 0.1$ criterion. This intercept indicates that at baseline conditions (e.g. rainfall less than 0.1 inches and less than 1 h CSO per time-window), the mean male-specific coliphages concentration in the CAWS is 2.4 PFU/100 mL ($10^{0.388}$). Since location is a random effect for the intercept, the mean male-specific coliphages concentration at a specific location may be higher or lower than 2.4 PFU/100mL. More specifically, if the random effect of location is included, the 95% confidence interval for the mean intercept is defined by $0.388 \pm 1.96 \times 0.828$ $\log_{10}$ PFU/100mL. This translates to a range of -1.23-2.01 $\log_{10}$ PFU/100 ml, or 0.06-100 PFU/100mL.

The rainfall threshold 0.1 inches model indicates that rainfall within 24 h of sample collection and >72-96 h since sample collection are associated with increased male-specific coliphages concentration. The same pattern is apparent for CSO. The model indicates than when rainfall exceeds 0.1 inches and CSO duration exceeds 1 h in the 24 h prior to sample collection, the mean male-specific coliphages concentration in the CAWS will be 20 PFU/100 mL ($10^{(0.388+0.128+0.795)}$). Including the location random effect, the 95% confidence range is 0.5-850 PFU/100mL. The effect of CSO in this time-window on male-specific coliphages concentration is greater than the effect of rainfall.

For the rainfall threshold 0.25 inches model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ somatic coliphage concentrations is 0.830, giving R^2 = 0.689. The model has intercept 0.353, but this is not statistically significantly different from zero. This indicates that the average concentration of male-specific coliphages in CAWS is near the limit of detection. Including the random effect of location on the intercept, the 95% confidence interval for the mean intercept is defined by $0.353 \pm 1.96 \times 0.825$ $\log_{10}$ PFU/100mL, which translates into 1.26-1.98 $\log_{10}$ PFU/100mL, or 0.06-94 PFU/100mL.

The rainfall threshold 0.25 inches model indicates that rainfall within 24 h of sample collection, and CSO in the 0-24 h and >48-96 h time-windows are associated with increased male-specific coliphages concentrations. The effect of CSO is greater than the effect of rainfall.

Table 14. Linear mixed effects models for $\log_{10}$ male-specific coliphages concentrations ($\log_{10}$ PFU/100 mL) in the CAWS.

	Coefficients	
Variable	**Rain ≥ 0.1 in**	**Rain ≥ 0.25 in**
Intercept	0.388*	0.353
Rain Category 4 (<24 h)	0.128*	0.255*
Rain Category 3 (>24-48 h)	0.009	0.109
Rain Category 2 (>48-72 h)	0.023	0.072
Rain Category 1 (>72-96 h)	0.222*	0.251*
CSO Category 3 (<24 h)	0.795*	0.705*
CSO Category 2 (>24-48 h)	0.149	0.095
CSO Category 1 (>48-96 h)	0.479*	0.520*
Random Effect Standard Deviation	0.827	0.825

**p* <0.10*

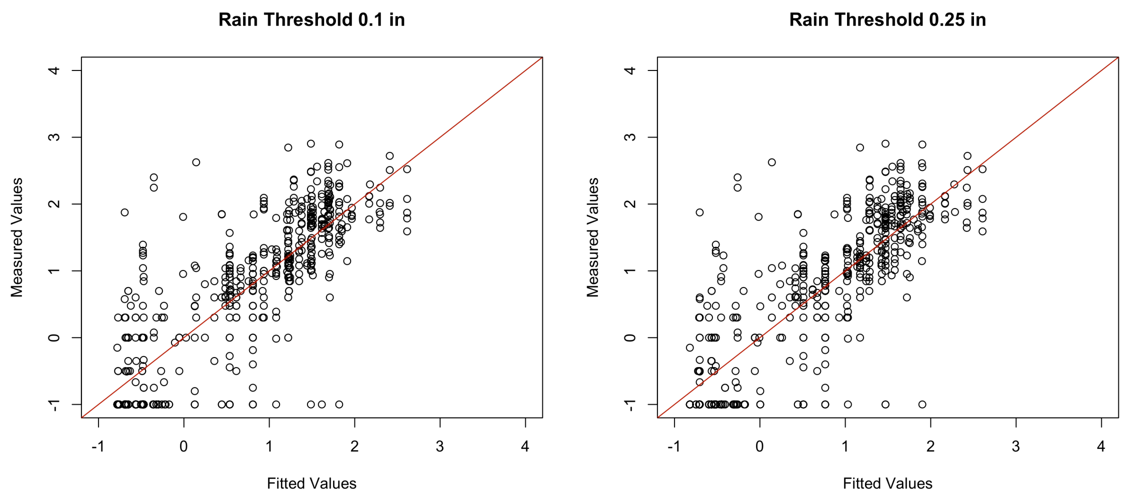

Figure 10. Measured versus fitted $\log_{10}$ male-specific coliphages concentrations ($\log_{10}$ PFU/100 mL) in linear mixed-effects models.

3.9 *Cryptosporidium* Oocysts Results

Linear mixed effects were fit with two rainfall thresholds – 0.1 inches and 0.25 inches– for each 24 h period. The coefficients of the fixed effects are summarized in Table 15. Scatter plots of the measured versus fitted $\log_{10}$ *Cryptosporidium* oocysts concentrations (Figure 11Figure 11) show that both models perform similarly, but that neither performs well. Both models systematically under-estimate the oocysts concentrations. The location random effect has standard deviation 0.248 and 0.266 $\log_{10}$ oocysts/10L for the 0.1 inches and 0.25 inches rainfall threshold models, respectively.

For the rainfall 0.1 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ oocysts concentration is 0.368, giving R^2 = 0.115.

This model has intercept -0.672 indicating that under baseline (e.g. “dry”) conditions (e.g. rainfall less than 0.1 inches and less than 1 h CSO per time-window), the mean *Cryptosporidium* oocysts concentration in the CAWS is 0.2 oocysts/10L ($10^{-0.672}$). Since location is a random effect for the intercept, the mean oocysts concentration at a specific location may be higher or lower than 0.2 oocysts/10L. More specifically, when the random effect is included, the 95% confidence interval for the intercept is defined as -0.672 ± 1.96 × 0.248 $\log_{10}$ oocysts/10L, which translates into 1.16- -0.186 $\log_{10}$ oocysts/10L, or 0.07-0.7 oocysts/10L.

The model indicates that CSO within 24 h of sample collection significantly increases the oocysts concentration, and that rainfall > 24-48 h prior to sample collection also significantly increases oocysts concentration. The effect of CSO is larger than the effect of rainfall, indicated by the larger coefficients. The model predicts the mean *Cryptosporidium* oocysts concentration given rainfall and CSO in the 0-24 h time-window to be 0.8 oocysts/10L. Including the random effect of location, the 95% confidence interval is 0.3-2.4 oocysts/10L. The overall model fit, however, is so poor that interpretation of these results should be limited.

For the model with the rainfall threshold 0.25, the Pearson’s correlation coefficient between the measured and fitted $\log_{10}$ *Cryptosporidium* oocysts concentrations is 0.362, giving $R^2 = 0.131$.

The model has intercept -0.596 $\log_{10}$ oocysts/10L, indicating that under baseline conditions, the mean oocysts concentration in the CAWS is 0.3 oocysts/10L. Including the random effect of location, the 95% confidence interval for the intercept is defined by -0.596 ± 1.96 × 0.266 $\log_{10}$ oocysts/10L, which translates into 0.08-0.9 oocysts/10L.

The rainfall threshold 0.25 inches model indicates than rainfall in the >24-48 h prior to sample collection and CSO in the 24 h prior to sample collection are associated with significant increase in oocysts concentrations. The rainfall coefficient for the 0-24 h time-window is statistically significant, but negative. Due to the poor model performance, interpretation of these results should be limited.

Table 15. Linear mixed effects models for $\log_{10}$ *Cryptosporidium* oocysts concentrations ($\log_{10}$ #oocysts/10L) in the CAWS.

Variable	Coefficients	
	Rain ≥ 0.1 in	**Rain ≥ 0.25 in**
Intercept	-0.672*	-0.596*
Rain Category 4 (<24 h)	-0.160	-0.312*
Rain Category 3 (>24-48 h)	0.592*	0.489*
Rain Category 2 (>48-72 h)	-0.067	-0.125
Rain Category 1 (>72-96 h)	0.037	-0.038
CSO Category 3 (<24 h)	0.735*	0.792*
CSO Category 2 (>24-48 h)	0.313	0.252
CSO Category 1 (>48-96 h)	0.205	0.142
Random Effect Standard Deviation	0.248	0.266

* $p < 0.05$

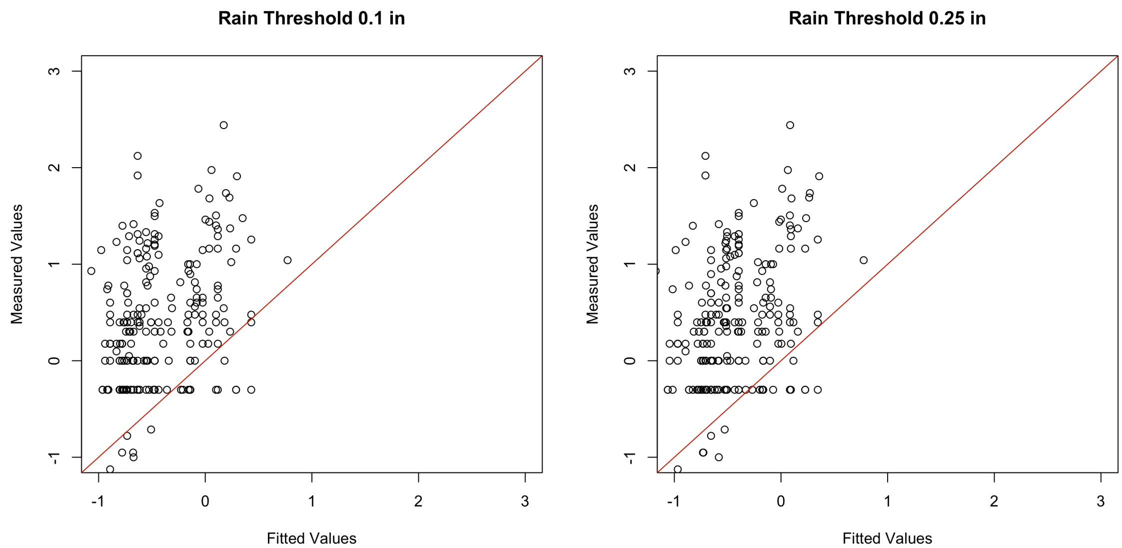

Figure 11. Measured versus fitted $\log_{10}$ *Cryptosporidium* oocysts concentrations ($\log_{10}$ #oocysts/10L) in linear mixed effects models.

3.10 *Giardia* cyst Results

Linear mixed effects were fit with two rainfall thresholds – 0.1 inches and 0.25 inches– for each 24 h period. The coefficients of the fixed effects are summarized in Table 16. Scatter plots of the measured versus fitted $\log_{10}$ *Giardia* cyst concentrations (Figure 12) show that both models perform similarly, but that the cloud shows wide variability around the line of concordance (red). The location random effect has standard deviation 0.957 and 0.956 $\log_{10}$ cysts/10L for the 0.1 inches and 0.25 inches rainfall threshold models, respectively.

For the rainfall 0.1 inches threshold model, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ cyst concentration is 0.743, giving $R^2 = 0.552$.

This model has intercept 0.586 indicating that under baseline (e.g. "dry") conditions (e.g. rainfall less than 0.1 inches and less than 1 h CSO per time-window), the mean *Giardia* cysts concentration in the CAWS is 4 cysts/10L ($10^{0.586}$). Since location is a random effect for the intercept, the mean cyst concentration at a specific location may be higher or lower than 4 cysts/10L. More specifically, when the random effect is included, the 95% confidence interval for the intercept is defined as $0.586 \pm 1.96 \times 0.957$ $\log_{10}$ cysts/10L, which translates into -1.29-2.46 $\log_{10}$ cysts/10L, or 0.05-290 cysts/10L.

The model indicates that CSO within 24 h of sample collection significantly increases the cyst concentration, and that rainfall in any time-window does not significantly alter the *Giardia* cyst concentration. The mean *Giardia* cyst concentration predicted by the model given rainfall and CSO in the 0-24 h time-window is 9.5 cysts/10L ($10^{(0.586+0.015+0.376)}$). Considering the random effect of location, the 95% confidence interval around this mean value is 0.13-710 cysts/10L.

For model with the rainfall threshold 0.25 inches, the Pearson's correlation coefficient between the measured and fitted $\log_{10}$ *Giardia* cyst concentrations is 0.744, giving $R^2 =$ 0.553.

The model has intercept 0.573 $\log_{10}$ cysts/10L, indicating that under baseline conditions, the mean cyst concentration in the CAWS is 4 cysts/10L. Including the random effect of location, the 95% confidence interval for the intercept is defined by $0.573 \pm 1.96 \times 0.956$ $\log_{10}$ cysts/10L, which translates into 0.05-280 cysts/10L).

The rainfall threshold 0.25 inches model similarly indicates that CSO in the 24 h prior to sample collection significantly increases the *Giardia* cyst concentration, but that the effect of rain is negligible on cyst concentration.

Table 16. Linear mixed effects models for $\log_{10}$ *Giardia* cysts concentrations ($\log_{10}$ #cysts/10L) in the CAWS.

	Coefficients	
Variable	**Rain ≥ 0.1 in**	**Rain ≥ 0.25 in**
Intercept	0.586*	0.573*
Rain Category 4 (<24 h)	0.015	0.071
Rain Category 3 (>24-48 h)	0.080	0.199
Rain Category 2 (>48-72 h)	0.119	0.080
Rain Category 1 (>72-96 h)	0.092	0.115
CSO Category 3 (<24 h)	0.376*	0.345*
CSO Category 2 (>24-48 h)	-0.134	-0.159
CSO Category 1 (>48-96 h)	-0.119	-0.114
Random Effect Standard Deviation	0.957	0.956

*$p < 0.05$

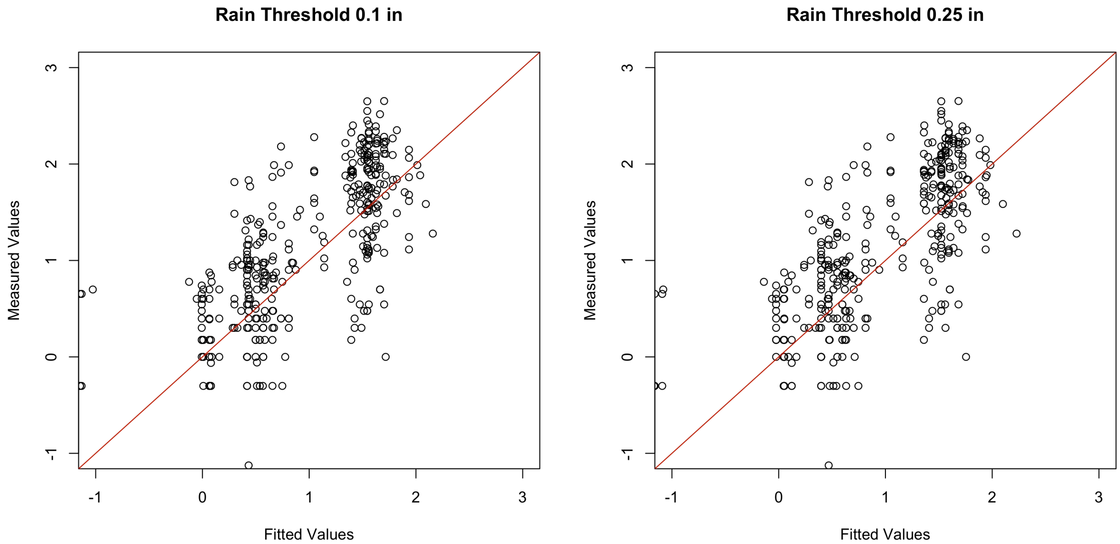

Figure 12. Measured versus fitted $\log_{10}$ *Giardia* cysts concentrations ($\log_{10}$ #cysts/10L) in linear mixed effects models.

4. Discussion

Statistical models were developed from a data-driven approach, and a conceptually-driven approach. In the data-driven approach, a large suite of potential explanatory variables were defined, and winnowed using binary regression tree models; subsequently linear and linear mixed effects models were used for final model fitting and selection. In the conceptually-driven approach, categorical variables that are readily interpreted for decision-making were developed that characterize rainfall and CSO above a specified threshold in time-windows prior to sample collection. In both approaches, ultimately linear mixed effects models with location as a random effect on the intercept were used. This approach enables the variability in microbe concentrations between locations in the CAWS to be included in the statistical models without inflating the number of explanatory variables, and thereby decreasing efficiency and power.

Models of *E. coli* concentration performed moderately, with $R^2 \sim 0.5$ (Table 17). The conceptually-driven model identified rainfall in the 0-24 h and > 24-48 h, and CSO in the 0-24 h time-window as significantly associated with increased $\log_{10}$ *E. coli* concentrations in the CAW (Table 11). The data-driven *E. coli* model included six main effect terms and six main effect interaction terms (Table 4), with variables that describe rainfall and CSO at long time-lags (e.g. time since the penultimate CSO – last.cso2 – and cumulative rain in the previous 96 h – h96.rain). Compared to the conceptually-driven model, the data-driven model has slightly better explanatory power, as indicated by the higher R^2 and lower random effect standard deviation, σ_l.

Models of enterococci, like those of *E. coli* performed moderately (Table 17). The conceptually-driven model identified rainfall in the 0-24 h, and to a lesser extent in the

>24-48 h, and CSO in all time-windows as significantly associated with $\log_{10}$ enterococci concentrations in the CAWS (Table 12). The direction of the coefficients for the CSO variables in time-windows 0-24 h and >48-96 h were positive, but negative in the >24-48 h time-window. Conceptually, one would expect that the coefficients for all CSO time-windows would be positive, and of decreasing magnitude with increasing time-lag. The presence of the negative coefficient for the >24-48 h CSO time-window may suggest the need for additional explanatory variables, or indicate that samples for which the most recent CSO is in this time-window have a unique quality.

Models of somatic coliphage performed well, with $R^2 > 0.75$ for both the data-driven and conceptually-driven models (Table 17). The conceptually-driven models identified the rainfall time-window of 0-24 h, and the CSO time-windows of 0-24 h and > 48-96 h as being significantly associated with increases in $\log_{10}$ somatic coliphage concentrations (Table 13). The coefficients for the CSO time-window >24-48 h are not significantly different from zero. The data-driven model included interaction terms between rainfall in the 72 h and 96 h prior to sample collection and the penultimate CSO (Table 6). Physically this doesn't make a lot of sense because many of the penultimate CSO events occurred more than 72 h or 96 h prior to sample collection. No variables pertaining to the most recent CSO event were in the final data-driven model.

Models of male-specific coliphages performed similarly to those for somatic coliphage, with $R^2 \sim 0.70$ (Table 17). The conceptually-driven model identified the same time-windows as were identified in the somatic coliphage model (Table 14). The data-driven model for male-specific coliphages, however, included only one variable pertaining to the penultimate CSO --- e.g. last.cso2 (Table 7). Other variables pertained to the most recent CSO, the last rain event, and cumulative rain in 72 h prior to sample collection. Physically, the variables with shorter time-lag are more plausibly associated with microbe concentrations than the penultimate CSO event variables in the somatic coliphage model.

Models of *Cryptosporidium* oocysts concentrations performed very poorly, with $R^2 < 0.33$ (Table 17). Diagnostic evaluations of both the data-driven and conceptually-driven model confirm what is indicated by the R^2 value, namely that the models do not have reliable predictive power. These models suggest that the $\log_{10}$ *Cryptosporidium* oocysts concentration in CAWS cannot be predicted by linear models containing rainfall and CSO variables: Factors other than rainfall and CSO determine the oocysts concentrations the CAWS.

Models of *Giardia* cyst concentrations performed moderately, with $R^2 \sim 0.55$ (Table 17). The conceptually-driven model identified only CSO in the 0-24 h time-window as significantly associated with increased *Giardia* cyst concentrations in the CAWS (Table 16). The data-driven model included only two variables – the time since last CSO (last.cso) and the magnitude of the last rain (mag.last.rain) – making it the simplest model of these analyses (Table 9). The random effect standard deviation for *Giardia*, however, is very large, $\sigma_l > 0.9 \log_{10}$ cysts/10L, indicating that the *Giardia* concentration varies widely between locations in the CAWS.

The conceptually-driven models for all microbes indicate that rainfall in the 24 h prior to sample collection is associated with increased microbe concentrations. The effect of more distant (in time) rainfall varies between microbes, and is more important in determining the concentrations of the indicator bacteria than those of the indicator viruses or *Giardia* cysts. Similarly, CSO event in the 24 h prior to sample collection is associated with increased microbe concentrations. The effect of more distant (in time) CSO events varies between microbes, and is more important in determining the concentration of enterococci and the indicator viruses. The unexpected coefficients for CSO events in the >24-48 h time-window for enterococci and the indicator viruses may reflect on the data collected – e.g. the samples that were collected with CSO events in this time-window may be unique – or may reflect incompleteness of the explanatory variables included in the model.

The data-driven models include unique combinations of rainfall and CSO event variables for each microbe. One surprising consistency in models of the indicator microbes is the presence of variables referring to the penultimate CSO events. The biological plausibility of this relationship is uncertain. The long time lag for most penultimate CSO events (on the order of weeks, rather than hours) would lead one to expect that the spike in microbe density in water resulting from this input should be dissipated from the CAWS prior to sample collection weeks later. That variables describing these CSO events are present in the model, may indicate that these overflows influence the total microbe load so that the effect of the event persists. This could be accomplished if, for example, the CSO event recharges sediment reservoirs, which discharge microbes slowly over time.

Ultimately, the conceptually-driven models indicate that the concentrations of the indicator microbes and *Giardia* differ in the CAWS under “wet” and “dry” conditions. The conceptually-driven model results suggest that a starting point for defining wet conditions may be rainfall greater than 0.1 inches or 0.25 inches in the previous 24 h and CSO event for more than 1 h in the previous 24 h. Further model development, however, will be required to optimize the selection of the thresholds and time-windows to meet specific policy objectives for microbial water quality.

The data-driven models have many variables with different units, and have different directions for their effect, which may hinder their interpretation of rainfall and CSO effects in the CAWS. The data-driven models, however, are better able to predict microbe concentrations, as indicated by the lower R^2 and lower random effect standard deviation.

Table 17. Comparison of linear mixed effect models based on the coefficient of determination (R^2) and the standard deviation of the random effect (σ_l). Conceptually-driven model summaries are based on models with the 0.1 inches rainfall threshold.

	Modeling Approach	
	Data-Driven	**Conceptually-driven**
E. coli		
R^2	0.524	0.497
σ_l	0.553	0.618
Enterococci		
R^2	0.480	0.454
σ_l	0.458	0.427
Somatic Coliphage		
R^2	0.762	0.751
σ_l	0.833	0.893
Male-Specific Coliphages		
R^2	0.711	0.685
σ_l	0.936	0.827
***Cryptosporidium* oocysts**		
R^2	0.327	0.115
σ_l	0.509	0.248
***Giardia* cysts**		
R^2	0.562	0.552
σ_l	0.918	0.957

5. References

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ITEM 2

Information requested by the Illinois Pollution Control Board regarding hand washing and illness in CHEERS

Prepared by
Samuel Dorevitch, MD, MPH
and the UIC CHEERS research group

December 30, 2010

CHEERS
WATER CHICAGO SPORTS

UIC UNIVERSITY OF ILLINOIS AT CHICAGO SCHOOL OF PUBLIC HEALTH

Background
The following questions were pre-filed by the People of Illinois for Samuel Dorevitch and Thomas Granato on October 4, 2010, before the Illinois Pollution Control Board ("the Board").

8. The CHEERS Final Report does not appear to indicate that the study asked participants whether they washed their hands and/or bodies following recreation on the CAWS or GUW.

a. Did you ask participants whether they washed their hands and/or bodies following recreation on the CAWS or GUW?

b. Do you have any information to discern whether either group of recreators was more fastidious than the other about washing following exposure to the water?

In the course of the oral response to that question at the October 19, 2010 hearings before the Board, a request was made for a more detailed response to that question, including an analysis of whether, if hand washing were taking into account, different conclusions might be reached regarding the health risks of CAWS recreation. This document is that written response.

<u>Response to pre-filed question 8a</u>
Participants in the water recreation groups (Chicago Area Waterways System [CAWS] and General Use Waters [GUW]) were asked the following 2 sequences of questions:

1) Did you eat during or after activities at river/lake today? y/n
    a. If yes, then did you clean your hands before you ate? y/n
        i. If yes, then what did you use to clean your hands?
2) Did you drink during or after activities at river/lake today? y/n
    a. If yes, then did you clean your hands before you drank? y/n
        i. If yes, then what did you use to clean your hands?

<u>Response to pre-filed question 8b</u>
There is evidence that eating during/after recreation was significantly more frequent among GUW participants than among CAWS participants. The frequency of eating among 7,710 water recreators during or immediately after recreation, by study group, is summarized in Table 1. The higher rate of eating among GUW study participants compared to CAWS participants is highly significant statistically (Chi-square p-value<0.0001).

Group	Ate	Did not eat	Total
CAWS	32.6%	67.3%	100%
GUW	41.7%	58.3%	100%
All	**37.1%**	**62.9%**	**100%**

Table 1: Frequency of eating during or after recreation, by study group

There is evidence that drinking during/after recreation was more frequent among GUW participants than among CAWS participants. The frequency of drinking among 7,710 water recreators during or immediately after recreation, by study group, is summarized in Table 2. The higher rate of drinking among GUW study participants compared to CAWS participants is highly significant statistically (Chi-square p-value<0.0001).

Group	Drank	Did not drink	Total
CAWS	61.0	38.9	100%
GUW	69.2	30.8	100%
All	**65.0**	**35.0**	**100%**

Table 2: Frequency of drink during or after recreation, by study group

Among those who ate immediately after recreation, CAWS participants were more likely to wash their hands, as summarized in Table 3. Among 2,856 water recreators, those in the CAWS group were more likely to wash their hands than those in the GUW group. This difference is highly significant statistically (Chi-square p-value<0.000).

Group	Never washed	Sometimes washed	Always washed	Total
CAWS	49.2%	1.0%	49.8%	100%
GUW	66.7%	0.5%	32.8%	100%
All	**58.8%**	**0.7%**	**40.5%**	**100%**

Table 3: Frequency of hand washing before eating, by study group.

Among those who drank immediately after recreation, CAWS participants were more likely to wash their hands, as summarized in Table 4. Among 5,013 water recreators, those in the CAWS group were more likely to wash their hands than those in the GUW group. This difference is highly significant statistically (Chi-square p-value<0.000).

Group	Never washed	Sometimes washed	Always washed	Total
CAWS	80.8	2.3	16.9	100%
GUW	85.3	1.2	13.5	100%
All	**83.1**	**1.8**	**15.1**	**100%**

Table 4: Frequency of hand washing before drinking, by study group.

Hand cleaning in relation to illness

The data were re-analyzed to model the occurrence of each of the health endpoints (AGI, ARI, skin rash, eye symptoms, ear symptoms) using a variable for hand washing. The variable had three levels: didn't eat or drank, ate/drank and washed hands, ate/drank and did not wash hands. The analysis was restricted to the 4,913study participants who ate and/or drank during or after recreation. For each of the five health outcomes, hand washing was added to the final predictive models of illness limited to the two water recreation groups (CAWS and GUW). Table 5 demonstrates that hand washing was a predictor of the development of skin rash but not the other health outcomes. However, the inclusion of the hand washing as a predictor in the model did not change the observation that the risk of developing skin rash were comparable for the two study groups; the odds ratio for CAWS (vs. GUW) was 1.115 (95% confidence interval 0.810-1.534, p-value=0.504).

Outcome	**p-value for "hand washing"**
Acute gastrointestinal illness	0.822
Acute respiratory illness	0.699
Ear symptoms	0.691
Skin rash	0.005
Eye symptoms	0.300

Table 5: Statistical significance of hand washing variable in 2-group (CAWS, GUW) models of illness.

The difference in the risk for AGI between the CAWS and GUW groups remained statistically insignificant (p=0.816) after adjusting for hand washing (among those who ate or drank). As noted in the CHEERS Final Report of August 31, 2010, eye symptoms were more frequent among CAWS recreators than among GUW recreators (about 11 more cases per 1,000 uses, Executive Summary page xxxviii). That analysis did not take into hand washing. The data were reanalyzed to account for difference in hand washing between the CAWS and GUW groups. In that analysis, the rate of illness for CAWS and GUW participants was no longer statistically significant (p=0.201). In other words, the higher rate of eye symptoms in the CAWS group was no longer apparent. However, in analyses of all participants (including those who did not eat or drink), all associations that had been significant without hand washing in the model remained significant, and all associations that were not significant without hand washing in the model remained non-significant.

ITEM 3

ITEM 3

UPDATE ON US EPA RECREATIONAL WATER QUALITY CRITERIA ACTIVITIES

A. Will EPA Address Inland Waters?

EPA has not yet indicated that it will, or will not, apply the new recreational use criteria to inland waters. EPA is not addressing the issue of secondary contact recreation in its work on the new recreational use criteria. Extrapolation of the new primary contact recreational criteria for beaches to inland waters appears to be a future policy decision.

EPA's recent report on this topic, published on December 6, 2010[1], suggests that if EPA were to apply these new primary contact recreational criteria for beaches to inland waters, they could state that application of the new criteria to inland waters "is expected to result in sporadic, mild illness at rates no higher and probably lower than those experienced in Great Lakes/coastal waters" (EPA, 2010 at 1). However (as discussed under Item B below), EPA also noted the need for flexibility in implementation of future criteria for inland waters, including exceptions for wet weather conditions and alternate criteria based on epidemiological studies and quantitative microbial risk assessment (QMRA).

In EPA's Critical Path Science Plan, EPA agreed to evaluate the applicability of the National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Study's Great Lakes data to inland waters (project P28).[2] Specifically, EPA agreed to "establish whether there are, or are not, significant differences to justify additional studies to support applicability of criteria to inland waters" for primary contact recreation, such as a separate epidemiological study or QMRA (EPA, 2007, at 3-22).

EPA reviewed thirteen reports and articles to address project P28, and does not appear to believe that new studies are needed, despite contradictory opinions by various researchers. In the inland waters study report, EPA states that:

> "Findings from these reports will be used to develop analyses that will support a decision of whether and how [ambient water quality criteria] AWQC can be extended to inland waters on the basis of epidemiology studies conducted as part of EPA's National Epidemiological and Environmental Assessment of Recreational (NEEAR) Water Study, which include the Great Lakes epidemiology studies." (EPA, 2010 at 3).

The report indicates that inland waters differ significantly from coastal waters and that researchers and stakeholders have expressed concerns "regarding both the scientific and practical considerations of extending AWQC developed for coastal waters to inland waters" (EPA, 2010

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[1] EPA. 2010. Applicability of Great Lakes NEEAR Dataset to Inland Recreational Water Criteria: Summary of Key Studies. EPA #823-R1-0002. water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/upload/SHPD_WA_1_17_Summaries-Report_12-6-10_508.pdf

[2] EPA. 2007. Critical Path Science Plan for the Development of New or Revised Recreational Water Quality Criteria. EPA Office of Water and Office of Research and Development. EPA 823-R-08-002, August 31, 2007, www.epa.gov/waterscience/criteria/recreation/plan/cpsplan.pdf.

at 3). To address these concerns, EPA examined differences including "epidemiology, hydrodynamics, fecal pollution sources, use patterns, and performance of indicator measurement techniques" (EPA, 2010 at 5) as well as sediment re-suspension and discharges from publicly owned treatment works (POTWs).

Some researchers believed "that insufficient evidence exists for direct extrapolation of criteria based on Great Lakes studies for use for inland waters." Others "recognized the imperative that new or revised criteria be developed and the low likelihood that additional epidemiology studies will be conducted in time for use in developing new or revised criteria … the group generally supported the position that AWQC derived from Great Lakes studies would likely be protective of public health at inland waters" (EPA, 2010 at 12). A common theme was that there was a scarcity of epidemiological studies of inland waters that could be used to inform the application of AWQC from coastal to inland waters. However, there were several statements in the report that EPA could apply the criteria to inland waters. The report also discusses using QMRA modeling, anchored to epidemiological studies, as a basis of evaluating health risks associated with different sources in inland waters (EPA, 2010 at 25).

One of the reports that EPA reviewed for the inland waters study report was its own review of literature[3]. Unfortunately, this report was not available for review. In the inland waters study report, EPA reported that a major finding of the literature review was that the "data and relationships from the Great Lakes waters studies, which are affected primarily by POTWs, can be applied to inland waters that are also affected primarily by POTW effluents" (EPA, 2010 at 15). However, EPA also acknowledged in the report that "there are no definitive epidemiological studies to support or preclude making the extension" of the criteria for POTW-impacted Great Lakes waters to inland waters (EPA, 2010 at 1).

B. <u>In Current Implementation Guidance, What Flexibility is There for States in Setting Water Quality Standards for Secondary Contact Waters?</u>

EPA has not established guidance for setting water quality standards for secondary contact recreation and has not indicated that it intends to develop such guidance in the future. Furthermore, EPA is not addressing secondary contact recreation in its current efforts to develop new recreational use criteria for beaches. All of the EPA's epidemiological-microbiological studies are designed to determine illness association with swimming-related activities involving immersion.

In EPA's review of whether the NEEAR data could be applied to inland waters, EPA noted that flexibility is provided under the current (1986) criteria for states to "designate specific classes of waterbodies or specific circumstances for different, scientifically defensible water quality standards. Such a designation could be made for waters known to be affected primarily by animal sources or for temporary changes in microbial water quality criteria following rain events" (EPA, 2010 at 23).

[3] EPA. 2010. Literature Review of Assessment of the Applicability of Existing Epidemiology Data to Inland Waters. Final report. Office of Water, Office of Science and Technology, Health and Ecological Criteria Division, Washington, DC.

EPA also noted that researchers agreed for the need for flexibility in implementation of new or revised primary contact criteria. These included "different criteria for beaches with different use patterns; discounting water quality measurements taken after rain events in concert with implementing risk management strategies for protecting human health; … and using temporary or permanent site-specific criteria" (EPA, 2010 at 13).

C. What is the EPA Direction in New Implementation Guidance for Secondary Contact Waters?

As discussed under Subsection B, EPA has not indicated that it will develop implementation guidance for secondary contact recreational waters. EPA's focus has been on developing rapid indicators, epidemiological-microbiological studies for primary contact recreation, and tools, such as QMRA and sanitary surveys. EPA has not specifically indicated that these tools and site-specific epidemiological studies could not be used to establish secondary contact criteria. However, existing guidance indicates that this flexibility should be available to States (as discussed in Subsection D below).

D. Will EPA Give States Flexibility to Consider Local Conditions and Epidemiological Studies in Setting Secondary Contact Water Quality Standards?

As discussed above in Item C, EPA has indicated that there is flexibility in current (1986) guidance for States to consider local conditions and epidemiological studies in setting site-specific primary contact water quality standards. There is no guidance for setting secondary contact water quality standards, nor does the scientific literature support selection of a specific risk level for secondary contact recreation. In the report from a 2007 experts' workshop on recreational criteria[4], EPA documented:

> "Workgroup members defined secondary contact as limited or incidental contact. As such, workgroup members believed that the same approach could be used for waters designated as secondary contact as used for primary contact, meaning that epidemiologically-based health data could be used to define acceptable exposure limits. QMRA could also be used for these purposes to supplement available epidemiological information." (EPA, 2007 at 28).

In the past, EPA has approved narrative criteria for secondary contact recreation without numeric criteria (e.g., Oklahoma in general and Rhode Island for Class C waters). EPA has also approved numeric criteria for secondary contact recreation (geometric mean) that is up to nine times greater than the primary contact recreation (e.g., Ohio, Kansas, Missouri). This suggests that with the advance of epidemiological-microbiological studies and tools such as QMRA, EPA should consider new (narrative or numeric) criteria that are protective of secondary contact recreational uses.

[4] EPA. 2007. Report of the Experts Scientific Workshop on Critical Research Needs for the Development of New or Revised Recreational Water Quality Criteria. Proceedings from Workshop at the Airlie Center, Warrenton, VA. March 26-30, 2007. Office of Water, Office of Research and Development, June 15, 2007.

ITEM 3

E. Slides, Webinar Materials and Other Information Showing Flexibility Being Considered by EPA in Recreational Water Quality Standards

- Current thinking by EPA that States could set site-specific criteria based on epidemiological studies and other tools. EPA's Development of New or Revised Recreational Water Quality Criteria Stakeholder Meeting, October 6-7, 2009 (see pdf page 2 of http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/upload/2009_12_22_criteria_recreation_oct2009_topic3.pdf) (copy attached)

- Stakeholder Webinar on EPA's Development of New or Revised Recreational Water Quality Criteria (see pdf page 24) http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/upload/Webinar-Oct2010.pdf (copy attached)

Discussion Topic 3: Sources of Fecal Contamination & Site-Specific Considerations

Shari Barash

Standards and Health Protection Division

USEPA

EPA

1986 Ambient Water Quality Criteria

- Do not differentiate based on sources of fecal contamination
  - "these values apply regardless of origin"
- Criteria apply unless:
  - "a sanitary survey shows that sources of the indicator bacteria are non-human AND an epidemiological study shows that the indicator densities are not indicative of a human health risk".

EPA

Current Thinking for 2012 Criteria

- Develop numeric criteria based on indicators of fecal contamination regardless of source.
- State would be able to develop and adopt regional, state, local or site-specific criteria
  - With epi study backed by sanitary survey, or
  - Other tools such as QMRA with enhanced sanitary investigation

Stakeholder Meeting on the Development of New or Revised Water Quality Criteria

EPA

Stakeholder Input

- Concern the 1986 criteria are "overprotective" in some situations and result in significant resource expenditures
  - Criteria exceedance due to non-enteric or animal fecal indicator sources that may not be correlated with human health effects.
  - Brief periods of time (few days) of criteria exceedance due to wet weather events.
- Prefer revised criteria to include options for applying different criteria values to waters with sources of fecal contamination that science shows are less risky than human sources
- Prefer EPA address how states should handle water body and source conditions different from those used to develop criteria (primarily POTW-impacted sites)

Stakeholder Meeting on the Development of New or Revised Water Quality Criteria

EPA

Current State of Knowledge

- Common sources of fecal indicator bacteria in ambient waters are:
  - POTW effluents
  - non-treated human sources (septic systems and CSOs)
  - animals (livestock and wildlife)
  - environmental habitats (sand, sediment)
- Different Pathogens/Different Potential Risks
  - Pathogen type and numbers vary among and within different fecal sources.
  - Only a limited number of human pathogens are associated with animal sources
    - Some organisms cause very severe diseases compared with the GI endpoint observed in epi studies.
  - POTW secondary treatment and certain disinfection techniques are not as effective for other classes of pathogens (viruses and protozoa) as compared to bacteria.

Current State of Knowledge (2)

- Epi studies have observed GI illness, but have not examined etiology
- Mission Bay, CA epi study
  - Mainly wildlife/avian sources
  - GI illness only correlated with the presence of the human bacterial marker and not with general indicator increases
  - Other wildlife/avian epi studies are currently being conducted which may or may not support the Missions Bay study results.
  - Limited information on sand contamination and bather load collected but not main focus of EPA epi studies.
    - More recent studies by others suggest a relationship and possible implication of sand exposure and health, but unclear on the relationship to water quality.
- To date, EPA has not identified available data to allow us to definitively develop criteria values for waters impacted by different fecal contamination sources.

Relevant EPA Activity Highlights

- Development of markers for human and bovine sources
- Data collection for agricultural animal Quantitative Microbial Risk Assessment (QMRA) for swine, poultry and cattle
- Data Collection and QMRA at POTW impacted site in tropical region in Boquerón, PR
- Urban Runoff epi study at Surfside, SC
- Sanitary survey/site characterization information collection for tropical POTW-impacted (Boquerón, PR) and urban runoff (Surfside, SC) beaches for use in QMRA
- Development of QMRA tool for use by states/stakeholders to use to incorporate site-specific considerations.

Relevant Activity Highlights – Non-EPA Studies

- SCCWRP epi study of shore bird/urban-runoff/non-POTW impacted site at Doheny, CA and shore bird/mixed sources site at Malibu, CA
- WERF project - Quantification of pathogens and sources of microbial indicators for QMRA in recreational waters
- University of Miami epi study (mixed urban sources)

Stakeholder Meeting on the Development of New or Revised Water Quality Criteria
EPA

Remaining Questions

- Is there a difference in risk between human and animal sources?
  – What hard science has been developed since the 2007 Experts Scientific Workshop at Arlie that informs this?
- Can we scientifically demonstrate and quantify such a risk difference?
- Can tools, such as sanitary surveys, source tracking, etc. allow us to confidently identify sources and estimate their relative influence (i.e., what percent risk do they contribute)? What about mixed sources?

Possible Approaches (1)

- Develop a criteria value used to protect recreation regardless of source based on POTW-impacted epi studies.

  - States could develop and adopt site-specific criteria that are scientifically defensible and protective of the swimming use.

Possible Approaches (2)

- If data are available and definitively show differences in risk from different sources*, EPA may develop distinct criteria values to be applied to waters that are impacted by different sources of fecal contamination
  - Rely on sanitary investigations and possibly source markers to demonstrate which sources are present/absent.

** No data identified to date*

Possible Approach (3)

- Approach 1, plus EPA would develop a tool (with default data) to provide to states and other stakeholders for performing site-specific QMRA in conjunction with an enhanced sanitary investigation.

Questions for Panel and Audience

- What has been your experience regarding identification of sources through sanitary investigations and/or source tracking studies? Have you found it easy or difficult to use these methods? Why?

- If EPA were to develop a QMRA tool (populated with default data) for use by states/stakeholders, what are the opportunities and challenges in using such a tool for addressing site-specific conditions? How can EPA make this tool most useful? What data is the most difficult/costly for states to obtain (e.g., infectivity, dose, fate and transport, exposure duration, fecal indicator concentration)?

- EPA has heard concerns that the 1986 criteria are over or under protective when applied to water bodies impacted by non-human sources. What has been your experience? And did you draw any conclusions about over or under protection? If so, based on what data?

Stakeholder Webinar on EPA's Development of New or Revised Recreational Water Quality Criteria

October 12
1 – 4 pm (EDT)

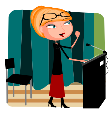
Agenda

1:00-1:15	Welcome and Introduction of Speakers
1:15-2:00	Update on EPA's Research for the development of Recreational Water Quality Criteria
2:00-2:30	Research Update Q&A
2:30-3:15	EPA's Current Thinking on Elements of Criteria
3:15-3:45	EPA's Current Thinking Q&A
3:45-4:00	Wrap Up

Today's Presenters

Charles Noss, Sc.D., ORD

John Ravencroft, Microbiologist, OST



Elizabeth Doyle, Chief, HHRAB, OST

Update on EPA's Research for the Development of Recreational Water Quality Criteria

UNITED STATES • ENVIRONMENTAL PROTECTION AGENCY

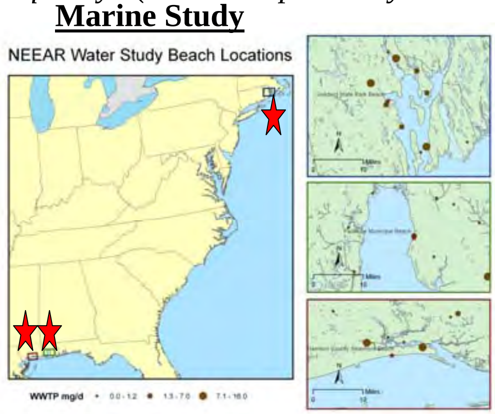
Epidemiology Studies

- 4 Freshwater studies conducted in Great Lakes (2003-2004)
- Studies conducted at 3 Marine locations (2005-2007)
- Study conducted at a marine beach impacted by urban runoff in a temperate region (2009)
- Study conducted in a tropical region (2009)

NEEAR Study Sites

Is there an association between illness and recreational water quality as measured by novel and rapid methods of determining water quality? (At sites impacted by treated sewage discharge)

Marine Study



Freshwater Study

Health, Exposure and Population

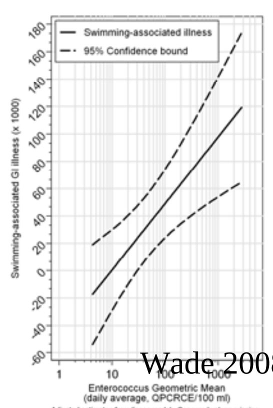
- *Health outcomes:*
  - o *Gastrointestinal illness (GI)*
    - – **Diarrhea (3 or more loose stools in a 24 hour period); Vomiting; Nausea and stomach ache; Nausea or stomach ache and impact on activity**
  - o *Upper respiratory illness (URI)*
    - – **Any two: sore throat, cough, runny nose, cold, fever**
  - o *Skin rash*
  - o *Eye irritations (watery eye or eye infection)*
  - o *Earache*
- *Swimming exposure:*
  - o *Immersed body in water*
- *Subpopulations Assessed :*
  - o *Children*
    - *Other subpopulations (elderly, pregnant…) did not have sufficient populations to assess*

7

NEEAR Water Study: Results

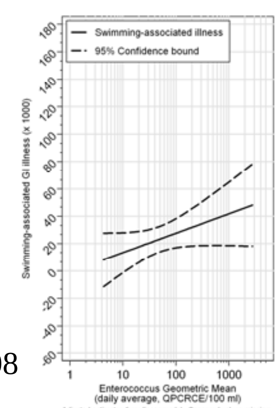
- Seven beaches
  - o Treated sewage impact
- *Enterococcus* qPCR CE
  - o Associated with gastrointestinal illness among swimmers
- Some evidence of high "sensitivity" among children in freshwater study
  - Status: Marine Study Manuscript Submitted
  - *Preliminary Results: Enterococcus* qPCR CE, *Bacteroidales*, qPCR CE showed associations with GI illness

Age 10 and under



Wade 2008

Age 11-54



8

Urban Runoff Epi Study at Surfside, SC

- Study Data Collection (29 days)
  - o 11,159 interviews from 5,205 households
  - o 530 water samples collected (at beach)
- Water Quality (*Enterococcus*)
  - o Good water quality
    - No days exceeded current criteria for marine water (not expected)
- Status: EPA report being externally peer reviewed
- Preliminary Results:
  - o Positive but statistically insignificant associations with Enterococcus CFU, Entero qPCR CCE and GI illness

Figure 2e: Surfside Beach contaminated sample locations

Figure 7: Schematic of Surfside Beach

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Tropical Waters Study at Boquerón, PR

- Study Data Collection (26 days)
  - o 15,726 interviews from 6,611 households
  - o 600 water samples collected (beach sites)
- Water Quality (*Enterococcus*)
  - o Good water quality
    - High proportion of samples (~30%) showed problems with the internal positive control assay
    - *Currently collecting additional samples and investigating reasons for qPCR interference*
- Status: EPA report being externally peer reviewed
- Preliminary Results:
  - o Good water quality, low exposure range, sample interference issue with qPCR
  - o qPCR/health association-difficult to interpret due to the sample interference and low detection of indicator bacteria

Figure 2d: Boquerón Beach contaminated sampling locations (yellow pins)

10

Quantitative Microbial Risk Analysis (QMRA) Status (P4)

- ***Objective:*** obtain pathogen and fecal indicator measurements from animal source manure run-off for use in QMRA
- ***Approach:*** field study with simulated rainfall and controlled application of fecal material from cattle, poultry and swine
- ***Status/Results:*** results from two simulations will be used in QMRA; late September rains have now allowed for sample collection for the stream run-off studies

11

qPCR Signal Fate and Transport (P8) Status

Objective: To evaluate how well molecular and culture-based indicators perform as surrogates for the pathogens

Approach: measure pathogen and fecal indicator levels in untreated and treated wastewater and persistence in discharged effluents

Status/Results*

- Draft Report currently undergoing external peer review
- Enterococci qPCR measurements persisted more than culture through chlorine and UV disinfection.
- Both qPCR and culture measurements degraded at similar rates in discharged effluents.
- Pathogens were not found consistently or at sufficient levels to assess persistence

12

**subject to change, based on external peer review comments and revision*

Archived Sample Storage and Re-analysis Contingency (P16, P22)

- Reanalyze archived samples using new indicators and develop health relationship for new indicators (P22), **if** frozen archived samples have not degraded (P16)

Sample Storage Stability (P16)

- How long can refrigerated samples be held before they should be processed for analyses?
- How long can samples be stored frozen before they significantly degrade?
- Have the frozen samples, archived from previous EPA conducted epidemiology studies, significantly degraded?

P16 Approach

- ***Short-term holding time:*** fresh refrigerated samples were held and analyzed at 24 and 48 hours
- ***Long-term holding time:*** frozen samples were held and analyzed at 6, 12, and 24 months
- ***Archived sample stability:*** frozen samples from 2003-2007 epidemiology studies were analyzed

P16 Status/Results*

- Draft report undergoing peer review
- 24 and 48 hr results were limited, conflicting and difficult to interpret
- 12 and 24 month samples were degraded
- Reanalyzed archived samples were degraded
- ***Conclusion:*** Archived samples should not be used for establishing health relationships with new indicators (P22)
- No recommendation on holding time due to inconclusive results, but limited data suggests that refrigerated samples should not be held for 24 hours or longer [Note: 6 hours used in NEEAR studies].

* Subject to change, based upon peer review comments and revision

Microbial Source Tracking P19-P21

P19: Develop novel cattle and human microbial source tracking methods and complete performance assessment with other published methods

P20: Evaluate human PCR and qPCR-based assays with water samples impacted with different levels of fecal pollution from a wide geographic range

P21: Evaluate cattle PCR and qPCR-based assays with water samples impacted with different levels of fecal pollution to supplement site characterization and quantitative sanitary investigation

P19 Status

- 4 peer-reviewed manuscripts
- Shanks, O.C., C. Kelty, M. Sivaganesan, M. Varma, and R.A. Haugland. Quantitative PCR for genetic markers of human fecal pollution. (2009) Applied and Environmental Microbiology 75 (17):5507-5513.
- Shanks, O.C., K. White, C.A. Kelty, S. Hayes, M. Sivaganesan, M. Jenkins, M. Varma, R.A. Haugland (2010). Performance assessment of PCR-based assays targeting *Bacteroidales* genetic markers of bovine fecal pollution. Applied and Environmental Microbiology 76:1359-1366.
- Shanks, O.C., K. White, C.A. Kelty, M. Sivaganesan, J. Blannon, M. Meckes, M. Varma, and R.A. Haugland (2010). Performance of PCR-based assays targeting *Bacteroidales* genetic markers of human fecal pollution in sewage and fecal samples. Environmental Science & Technology 44:6281-6288.
- Haugland, R.A., M. Varma, M. Sivaganesan, C.A. Kelty, L. Peed, and O.C. Shanks (2010). Evaluation of genetic markers from the 16S rRNA gene V2 region for use in quantitative detection of selected *Bacateroidales* species and human fecal waste by qPCR. Systematic and Applied Microbiology: In Press.

P19 Key Findings

- **All assays:**
  - Most assays were not 100% specific
  - Different assays cross-reacted with different animal sources
  - Use of multiple assays required for full coverage
- **Bovine-associated assays:**
  - Large variability in performance between cattle populations
  - Animal management practices may influence performance
  - Must test local populations before use
  - Need for further method development
- **Human-associated assays:**
  - Many assays were highly specific
  - DNA targets widely distributed in untreated sewage
  - Ready for fate & transport and water quality case studies

P20 Status

- One manuscript submitted for review
- Green, H.C., O.C. Shanks, M. Sivaganesan, R.A. Haugland, and K.G. Field (2010). Extended survival of human fecal *Bacteroides* in marine water. Submitted to: Environmental Microbiology (August 2010).

P20 Key Findings

- Significant difference in decay of genetic markers in marine and freshwater systems.
- Significant difference in decay of *Enterococcus* genetic markers and cultivatable cells when exposed to sunlight.
- *Enterococcus* and *Bacteroides* genetic markers exhibit different decay profiles in same environment.
- General and host-associated *Bacteroides* genetic markers respond to the environment in a similar manner.
- Decay coefficients for genetic markers in manure amended soils available for QMRA modeling.

P21 Status

- One manuscript submitted for review
- Rogers, S.W., M. Donnelly, L. Peed, C.A. Kelty, S. Mondal, Z. Zhang, O.C. Shanks (2010). Decay of bacterial pathogens, fecal indicators, and real-time quantitative PCR genetic markers in manure amended soils. Submitted to: Applied and Environmental Microbiology (September 2010).

P21 Key Findings

- Predicted survival times of some fecal indicators and pathogens exceeded 1 year
- Concentrations of the pathogens and general fecal indicator genetic markers were correlated (r=0.528-0.745).
- Host-associated genetic markers decayed to non-detectable concentrations long before other fecal indicators and pathogens.
- Decay coefficients for genetic markers in manure amended soils available for QMRA modeling.

Beach Modeling Studies (P23-P25) Status

- ***Objectives:*** refine Virtual Beach model building prediction capabilities
- ***Approach:*** collect freshwater and marine fecal indicator and environmental data
- ***Status/Results:***
  - o Builds models using culture and qPCR data
  - o Report titled *"Predictive Modeling at Beaches-Volume II: Predictive Tools for Beach Notification,"* on results and Virtual Beach software, is undergoing external peer review

Avian Assays P39 Status

- **<u>Identify</u>** genetic sequences useful in chicken and seagull specific fecal source (P39-1)
  - o Identified genetic sequences for assays for chicken (3 sequences), seagull (1 sequence) and Canadian goose (1 sequence)
  - o Continuing to develop new markers for these and related waterfowl
- **<u>Evaluate</u>** chicken and seagull specific fecal source assays for specificity and sensitivity (P39-2)

P39-1 Status

- Lu, J., J. W. Santo Domingo, S. Hill, and T. A. Edge. 2009. Microbial Diversity and Host-specific Sequences of Canadian Goose Feces. Appl. Envir. Microbiol. 75(18):5919-26.
- Lu, J. and J.W. Santo Domingo. 2008. Turkey fecal microbial community structure and functional gene diversity revealed by 16S rRNA gene and metagenomic sequences. J. Microbiol. 46:469-477.
- Lu, J., J.W. Santo Domingo, R. Lamendella, T.Edge, and S.Hill. 2008. Phylogenetic diversity and molecular detection of gull feces. Appl. Environ. Microbiol. 74: 3969-3976.

P39-2 Key Activities

- Evaluation of the performance of avian markers in the detection of fecal sources in environmental waters
- Detection limits of avian-specific PCR assays against fecal and water DNA extracts
- Use of currently available avian markers in a quantitative manner
- Evaluation of the chicken markers in fate and transport studies
- Determine the correlation between waterfowl host-specific targeted populations with bacterial indicators (e.g., enterococci), and bacterial pathogens (i.e., *Campylobacter*) in fecal and water samples

Conduct Expert Scientific Workshop

- **Objective:** Obtain input on what future science and research might be conducted to further improve our understanding of potential human health risks from exposure to fecal contamination from avian and other wildlife in coastal recreational waters.
- **Date:** Fall, 2011
- **Location:** to be determined

Conduct statistical analysis of children data from epidemiologic studies - P29

- *Children assessed as a subpopulation in all epidemiological studies*
    - o *Elevated risk in freshwater studies*
    - o *Other subpopulations (elderly, pregnant…) did not have sufficient populations to assess*
- *Assessment for marine studies ongoing (under peer review)*
- *Several potential factors*
    - o *Time spent in water, more likely to swallow water*

Quantitative Microbial Risk Assessment (QMRA) for Agricultural Animals

- EPA is conducting a QMRA (project P4 in CPSP) to estimate illness at a freshwater beach impacted by agricultural animal sources of fecal contamination.
- The risk assessment is based on microbes that are pathogenic to humans (e.g., *E. coli* O157:H7, *Cryptosporidium*, etc.) and come from ag. animal sources.

Quantitative Microbial Risk Assessment (QMRA) for Agricultural Animals [cont.]

- Evaluated the risk assessment approach in comparison to the NEEAR freshwater epi study results – “anchoring”
- Conducted field studies with simulated rainfall and controlled application of fecal material from cattle, poultry and swine
- Surveyed the scientific literature for information on zoonotic pathogen occurrence, distribution, prevalence, infectivity, and other parameters for use in the risk assessment.

Quantitative Microbial Risk Assessment (QMRA) for Agricultural Animals [cont.]

- Risk assessment is currently underway
- Incorporating the results from targeted field studies into the exposure assessment models
- Results should help inform on the relative nature of human health risks from various fecal sources

Enhanced Sanitary Investigation Tool

- Enhanced sanitary investigation instrument was developed that captures information sufficient to support the conduct of a QMRA
- The form was tested at EPA epi study sites in 2009.

Validation of Analytical Methods for Ambient Water Testing

- EPA completed a single-laboratory validation study of EPA's quantitative polymerase chain reaction (qPCR) procedures for the quantitative detection of enterococci (Method A) and Bacteroidales (Method B), in fresh and marine waters
- The purpose of the study was to:
  - optimize the methods (to further refine)
  - assess method performance in the single laboratory environment across multiple matrices
  - facilitate future modification of the two methods
  - provide a basis for a multi(ple) laboratory validation study
  - develop draft quantitative quality control (QC) acceptance criteria
- The draft methods are published (Method A: Enterococci EPA-821-R-10-004 and Method B: Bacterdoidales EPA-822-R-10-003) on the EPA web site at: http://www.epa.gov/waterscience/methods/method/biological/
- A multi-lab validation study for the two methods is underway for marine waters and the freshwater study will begin next spring

Evaluation of Indicator/Method Combinations

- EPA is evaluating indicator/method combinations for use in new or revised criteria
- Performance criteria for important features being evaluated include:
  - indicator/illness health relationship established
  - limit of detection
  - sensitivity
  - specificity
  - precision
  - percent false positives and false negatives
- Also evaluating qPCR and culture methods qualitatively to determine, for implementation purposes, appropriateness for each Clean Water Act program.

Indicators/Methods – Wastewater

- EPA has determined, based on the preliminary results of the studies in P8 and P18 that a new or revised wastewater test method is not necessary.
- The preliminary results from the P8 study indicate that the Enterococci qPCR method measures DNA levels in both wastewater and receiving ambient waters.
- The preliminary results from the P18 study indicate that existing culture methods approved for wastewater may be sufficient.
- Therefore, based on the results available at this time, a new wastewater method is not needed.

Other Indicator/Method Efforts

- Developing Approaches to Bring Additional Indicator/Methods into Criteria
  - Establish scientifically defensible “equivalency” of indicator/methods with an unknown health relationship to indicator/methods with an established health relationship.

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Monitoring & Modeling

- EPA is preparing a report that describes the temporal and spatial variation associated with water sampling.
  - o Considerations for developing sampling plans for beach monitoring
    - Inland vs. coastal
    - Where, when and how to sample
- Catalog and evaluate existing information on models and other tools to predict water quality at beaches and discuss protocols for model development.
- Predictive Models:
  - o Provide results in a “timely manner”
  - o Supplement to water sampling, not replacement

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Inland Waters

- EPA is preparing a report to support its evaluation of applicability of NEEAR Great Lakes data to inland waters
  - o Summarizes work of EPA and WERF related to assessing similarities and differences in inland waters, including:
    - Input from experts during February 2009 WERF Experts Inland Waters Workshop
    - Literature review of occurrence, persistence, fate & transport of indicators and pathogens in inland v. coastal settings
    - Comparison of Culture and qPCR methods
    - Method performance in inland fresh waters

Literature Reviews

- EPA conducted literature reviews to establish the state of the science in various areas related to criteria development.
- Two reviews have been published on EPA's recreational water quality criteria website
  - o http://www.epa.gov/waterscience/criteria/recreation/
  - o **"Review of Published Studies to Characterize Relative Risks from Different Sources of Fecal Contamination in Recreational Water",** EPA 822-R-09-001, CPSP P#30
  - o **"Review of Zoonotic Pathogens in Ambient Waters",** EPA 822-R-09-002, CPSP P#31
- One other is in progress (i.e., incorporating the results of EPA's 2009 Boqueron, Puerto Rico efforts).
  - o "**Review of Fecal Indicator Organisms Behavior in Ambient Waters and Alternative Indicators for Tropical Regions**" (P32)

EPA's Current Thinking on Elements of Criteria

EPA's Current Thinking Agenda

- No national-scale discounting for source anticipated
- Potential flexibilities for States
- Anticipated indicators and methods of measurement
- Human health risks from different fecal sources

No National-Scale Discounting For Source Anticipated

- Data supporting national-scale discounting for sources of fecal contamination have not been identified
- Criteria will likely depend upon epidemiology data from POTW-impacted beaches
- A combination of sanitary survey, QMRA and/or site-specific epidemiology studies may provide an option for states

Potential Flexibilities for States

- Consideration for incorporation of new technologies
  - o Criteria recommendations will incorporate indicator/methods which have demonstrated a health relationship in epi studies
  - o Molecular and other novel methods are evolving rapidly
  - o Newer evolving methods may not have been linked to health through epi studies
  - o States may want to consider the use of new technologies in water quality standards
- Consideration for Alternative Test Procedure (ATP)
  - o States and vendors may want to demonstrate “comparability” for alternative qPCR methods
- EPA would provide methodologies for use in demonstrating “equivalency” of new technologies and “comparability” of alternative test methods

Approaches for Incorporation of New Technologies

- Approaches Being Evaluated by EPA
  - o Comparison of results of side by side analyses to determine if there is a predictable relationship between the results
  - o States may incorporate procedures for developing criteria values, or develop site-specific alternatives to standards
  - o A description of a possible approach to demonstrating method equivalence will be available in parallel with the final criteria

Alternative Test Procedure (ATP)

- The ATP protocol describes a series of lab tests with which one determines comparability between a Reference Method and a Candidate Method.
  - o Establishes a definition for determining comparability of a laboratory method result for a **genetic method** ATP for microbes.
  - o Analytical microbiological methods are comparable if
    - Same measurement technique
    - Measure the same analyte
- EPA is currently developing the genetic method ATP (Final version Dec. 2013)

Alternative Test Procedure (ATP) [cont]

- o Examples of **comparable tests**:
  - two membrane filtration (MF) culture methods for Enterococci
  - two MTF culture methods for Enterococci
  - two qPCR methods for Enterococci that use different platforms (instruments)
- o Examples of tests that are **not comparable**
  - a MF and a MTF culture method for Enterococci (different determinative technique)
  - a qPCR method and a RFLP method for Enterococci (both are genetic methods, but are different determinative techniques)
  - a MF method for Enterococci and a MF method for E. coli (different analyte)
  - a qPCR method and a culture method for Enterococci (different determinative technique)
  - a qPCR method for Enterococci that uses a different DNA standard

Tools for Development of Site-Specific Criteria

- EPA is working to identify and develop tools to assist with development of site-specific criteria by states
- Would allow for development of alternative criteria value as long as same level of risk is achieved
- May include:
  - o Sanitary survey investigation and epi study
  - o Sanitary survey investigation and QMRA

Anticipated Indicators and Methods of Measurement

- Plan to provide a combination of methods based upon qPCR and culture
  - o Enterococcus qPCR and culture
  - o *E. coli* culture
- Intended to
  - o Provide implementation flexibility to states
  - o Align costs and sampling needs with purpose of monitoring

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Human Health Risks from Different Sources

Human Health Risks from Different Sources

- Recreational water epidemiology studies provide information on the:
  - o Nature and extent of health effects (e.g., GI illness)
  - o Relative magnitude of risks (swimmer vs. non-swimmer)
  - o Association between the degree of fecal contamination (as measured by FIB levels) and levels of observed illnesses in swimmers
- These studies have not provided substantial information about the specific microbial agents that are responsible for the observed illnesses.
  - o This information is important to understand risks for a wide variety of waterbody types and contamination sources

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Goals of QMRA Activities Related to Sources of Fecal Contamination

- Examine the human health risks from exposure to recreational waters impacted by different sources of fecal contamination
- Understand which pathogens could cause illnesses to swimmers in waters impacted by specific sources of fecal contamination
- Evaluate the extent to which recreational water risks vary with the sources of contamination

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Understanding Human Health Risks in POTW-impacted freshwaters

- We examined the reported epidemiologic results from studies conducted on the Great Lakes (i.e., beaches impacted by treated and disinfected effluent) in the US during 2003 and 2004 to estimate pathogens that could have caused the observed illnesses using QMRA.
- Soller et al. 2010. *Estimating the primary etiologic agents in recreational freshwaters impacted by human sources of faecal contamination*. Water Research. 44:4736-4747

Results from QMRA in POTW-impacted freshwaters

- Relatively few pathogens appear to cause the vast majority of illnesses.
- Human enteric viruses, and in particular norovirus, could have caused the vast majority of the observed swimming associated GI illnesses during the 2003/2004 epidemiology studies.
- The reverse QMRA is leading to a better understanding of freshwater POTW impacted waters.

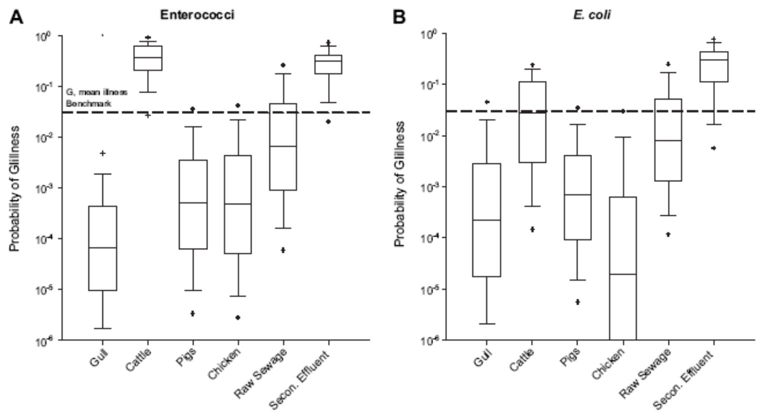
Relative Risks from Various Animal Sources

- Objective:
  - o Predict relative risks of illness from ingestion of recreational water that is assumed to be contaminated with feces from a range of animals (human, cattle, pigs, poultry and gulls).
- Main question:
  - o Are the relative risks from recreation in waters impacted by gulls, poultry, pigs, and/or cattle substantially different than those associated with recreational waters impacted by human sources?

Relative Risks from Various Animal Sources

- Evaluated “End of Pipe” scenarios for human, cattle, pigs, poultry and gulls.
  - o For human, this meant using literature reported levels of pathogens and indicators found in treated, disinfected effluent and raw sewage
  - o For cattle, pigs, poultry and gulls, this meant a ‘direct deposition’ event using literature reported data for pathogen and indicator levels found in their respective feces.
- Compared predicted illness rates for human impacted to non-human impacted waters at “fixed” FIB levels

Relative Risks from Various Animal Sources – Results



Soller et al. 2010. *Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination*. Water Research 44:4674-4691

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Relative Risks from Various Animal Sources – Conclusions

- This is an initial step to understand the relative risks from exposure to recreational waters impacted by gulls, poultry, swine, and/or cattle and to compare them with POTW effluent impacted waters
- The illness risk associated with non-sewage impacted beaches appears to depend on the source of contamination, i.e. some animals show relatively lower risks than others, which could account for the conflicting epidemiology findings

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Limitations

- No national level non-human source exclusion from the criteria due to limitations of available data
- EPA will not have sufficient data to develop different criteria values for different fecal sources
- Uncertainty involved with determining the proportion of human fecal material that may represent the dominant risk in a mixed-source situation
- Uncertainty involved with evaluating the differential disease endpoints between some zoonotic and human pathogens (e.g., *E. coli* O157:H7 versus norovirus).

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Resources

- rec_criteria@epa.gov
- http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/index.cfm
- http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/health/recreation/oct2010_index.cfm

THANK YOU

ITEM 4

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO'S LEGAL MEMORANDUM ON "PROTECTED WATER" ISSUE

I. Introduction

This memorandum addresses the issue of whether the CAWS is a "protected water" in accordance with 35 Ill. Adm. Code § 302.209, such that disinfection is required for the CAWS. During the October 19, 2010 hearing in the CAWS UAA rulemaking, the District's witness, Dr. Thomas Granato, was asked the following series of questions, which led to the submittal of this legal memorandum:

Mr. Harley: Keith Harley, Southeast Environmental Task Force. Mr. Granato, are you familiar with any water quality standards that presently exist in Illinois law that might apply to the CAWS?

The Witness: Water quality standards?

Mr. Harley: Yes.

The Witness: That apply to the CAWS?

Mr. Harley: Yes.

The Witness: Well, there's [sic] portions of the CAWS that currently are designated as general use.

Mr. Harley: Those portions that are not presently designated as general use in light of the Board's decision in sub docket A that the CAWS flow through recreational areas through parks and residential areas, are you familiar with the standards that apply to protective [sic] waters under Illinois law?

Mr. Andes: First, I'll object. You're characterizing the Board's first notice and sub docket A and I would object to the characterization. If we want to get into a legal argument about the protective waters, we can do that, but I don't know if you want to go there.

Ms. Tipscord: I would note for the record that the Board has proposed for first notice recreational use designations and with that caveat I think you can – is Mr. Granato aware?

The Witness: The protected waters – I'm somewhat familiar with it, yes.

Mr. Harley: Are you familiar with the fact that protected water designation requires seasonal disinfection?

The Witness: Can you repeat the question, please?

Mr. Harley: Are you familiar with the fact that the designation of protected waters would require seasonal disinfection?

The Witness: Yes, I'm familiar with that fact.

Mr. Harley: Has the District come to a conclusion based on the Board's decision whether or not the CAWS is properly characterized as protected waters?

The Witness: It's our position that they are not – should not be characterized as protected waters.

Mr. Harley: Why not?

Mr. Andes: Are we asking for a legal opinion here? That's really a legal determination.

Ms. Tipscord: Mr. Granato is here – Dr. Granato is here speaking on behalf of the District and he is asking for the District's position. If Dr. Granato can't answer to the District's position, that's fine, but the District obviously has a position. He just said what their position was.

The Witness: So it's our position that they don't meet the outline requirements in the part 304 – I can't remember where it is now. They don't meet the criteria outlined in the regulations.

Mr. Harley: Can you describe in what way?

Mr. Andes: Can I ask for the District to be able to submit a memorandum on that legal issue rather than Dr. Granato – there have been no questions that have been asked of Dr. Granato asking to state a legal conclusion on these issues. We would like the opportunity to submit our explanation of the issues.

Ms. Tipscord: You –

Mr. Harley: As a hearing officer, he is testifying that there is no applicable water quality standards for the CAWS and is saying this rulemaking should be delayed until such time that there are legally applicable water quality standards for the CAWS. I am positing my question that based on the Board's decision there may be actually legally presently decisive water quality standards for the CAWS. It's entirely appropriate for me to ask this question.

Ms. Tipsord: And, again, I think that Mr. Harley is asking for the position that Dr. Granato says is the District's position. I'm not asking for a legal opinion, but he is asking if you'll explain the District's position. If the District feels that requires a legal position, they can certainly address it.

Mr. Andes: We'll do that.[1]

[1] October 19, 2010 Hearing, Transcript at pp. 243-47.

Following up on the above testimony, this memorandum contains the District's legal analysis of the issues raised by Mr. Harley. The conclusions of that analysis are as follows: (1) the CAWS does not fall within the definition of "protected waters" under the relevant Illinois regulations; and (2) the eventual actions of the Board in Subdocket A will not change that conclusion.

II. Definition of "Protected Waters" in 35 Ill. Adm. Code § 302.209

The term "protected waters" is defined in 35 Ill. Adm. Code § 302.209 as follows:

> Section 302.209 Fecal Coliform
>
> a) During the months May through October, based on a minimum of five samples taken over not more than a 30 day period, fecal coliform (STORET number 31616) shall not exceed a geometric mean of 200 per 100 ml, nor shall more than 10% of the samples during any 30 day period exceed 400 per 100 ml in protected waters. *Protected waters are defined as waters which, due to natural characteristics, aesthetic value or environmental significance are deserving of protection from pathogenic organisms. Protected waters will meet one or both of the following conditions:*
>
> *1) presently support or have the physical characteristics to support primary contact;*
>
> *2) flow through or adjacent to parks or residential areas.*[2]

III. The CAWS Waters Are Not "Protected Waters"

The definition of "protected water" under 35 Ill. Adm. Code § 302.209 requires more than simple proximity to parks or residential areas. Instead, the language demands that protected waters must also have "natural characteristics, aesthetic value or environmental significance" that justifies protection from pathogenic organisms. Although the proximity to parks and residential areas is one condition and characteristic of a protected water, it also must have natural characteristics, aesthetic value or environmental significance that justifies protection – something more than exists for other waters, since if all waters qualify, then there is no point to having this detailed provision. There is no evidence in the rulemaking record showing that the CAWS waters have special significance, beyond other waters, that meets the tests in the "protected waters" rule. Moreover, as shown by the Risk Assessment and the CHEERS study, the evidence in this record indicates that there is no need here for additional, special "protection from pathogenic organisms," and requiring disinfection would provide no additional benefit to public health. The CAWS waters are not "protected waters" under the regulations.

It should be noted that any suggestion that seasonal disinfection already is required on the CAWS, on the basis that they are "protected waters," contravenes the entire basis of the CAWS UAA rulemaking. In starting this rulemaking, the IEPA indicated that effluent disinfection on

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[2] 35 Ill. Adm. Code § 302.209(a)(emphasis added).

the CAWS currently is not required.[3] Indeed, that is the whole reason that IEPA began this rulemaking, at least as to the issues now in Subdocket B. If seasonal disinfection already was required because the CAWS is a "protected water," there would be no reason for the parties in this matter to have expended such a vast amount of time, effort, and resources on this multi-year, enormous rulemaking endeavor.

[3] IEPA, *Statement of Reasons* at 98 (stating that "[i]n Part 304, the Agency is proposing a technology-based effluent limitation that mandates disinfection by dischargers to the majority of affected waters.")

IV. IEPA's Proposed Use Designations Would Not Change the Status of CAWS Waters as Not "Protected Waters."

The CAWS waters are currently designated as "secondary contact and indigenous aquatic life" waters. The IEPA proposal would change the designations, for recreational use purposes, so that each segment of the CAWS would fall into one of three categories: "incidental contact recreation," "non-contact recreation," or "non-recreation." These new designations would not affect whether the CAWS is a "protected water," because the regulatory definition of "protected waters" is not dependent upon the use designation. The definition of "protected water" is a two part test. First, there must be "natural characteristics, aesthetic value or environmental significance [that] are deserving of protection from pathogenic organisms."[4] If that element is met, the second prong of the test must be satisfied through a showing of at least one of the following two criteria: (1) presently support or have the physical characteristics to support primary contact; or (2) flow through or adjacent to parks or residential areas.[5] The precise language used in the recreational use designations is not relevant to meeting these tests.

V. CONCLUSION

For the reasons, set forth above, the CAWS is not a "protected water" under the Illinois regulations, and seasonal disinfection is not required under 35 Ill. Adm. Code § 302.209. Moreover, the recreational use designations that the Board will establish under Subdocket A of the CAWS UAA rulemaking will not affect that conclusion.

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[4] *Id.*

[5] *Id.*

ITEM 5

ITEM 5

BASIS FOR CALCULATION OF 15% INCREASE TO TAXPAYERS

On or around May 11, 2010, a comparison was made of the additional costs to taxpayers for disinfection as compared to the 2009 adjusted levies and adjusted tax rates. At that time, the District's overall adjusted tax rate was estimated at 26.01 cents per $100 of EAV. For the purpose of comparison, disinfection costs of $22 million in O&M costs were added to the Corporate Fund levy and $40.1 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $500 million in bonds at 5% to be paid over 20 years using one annual payment for a level debt service. The 2007 EAV was used in both calculations because it was the latest available at the time. The 2009 tax rate, including these disinfection cost equals 29.99 cents per $100 of EAV. This is an increase of approximately 3.98 cents per $100 of EAV or 15.3 percent from the estimated adjusted tax rate. Table 1 details the comparison.

Table 1

COMPARE TAX LEVIES 2009 - ALL FUNDS

LEVIES	2009 As Adjusted	2009 w/Disinfection
Corporate Fund -- $22 Million O&M	$ 236,027,000	$ 258,027,000
Construction Fund	9,090,000	9,090,000
Stormwater Management Fund	8,849,000	8,849,000
Retirement Fund	26,751,300	26,751,300
Reserve Claim Fund	3,182,000	3,182,000
Subtotal	$ 283,899,300	$ 305,899,300
Bond Redemption & Interest Funds:		
$500M Bonds for Disinfection		40,100,000
Subtotal Bond Redemption & Interest Funds	$ 157,341,350	$ 197,441,350
TOTAL	$ 441,240,650	$ 503,340,650

COMPARE TAX RATES 2009 - ALL FUNDS

TAX RATES Per $100 in Equalized Assessed Valuation FUND	2009 ADJUSTED		2009 w/Disinfection			
Gross Corporate Fund	15.13	¢	16.54	¢		
Construction Fund	0.58		0.58			
Stormwater Management Fund	0.57		0.57			
Retirement Fund	1.72		1.72			
Reserve Claim Fund	0.20		0.20			
Subtotal	18.20	¢	19.61	¢		
Bond Redemption & Interest Funds:						
Subtotal Bond Redemption & Interest Funds	7.81	¢	10.38	¢		
TOTAL	26.01	¢	29.99	¢	15.3%	increase

2007 Equalized Assessed Valuation of $155,972,794,427 was used to adjust 2009 tax rates.

ITEM 6

ITEM 6

ESTIMATION OF INCREASES IN USER CHARGE RATES FOR INDUSTRIAL USERS AND TAX EXEMPT USERS

The Metropolitan Water Reclamation District of Greater Chicago (District) maintains and enforces a user charge ordinance under authority of 70 Illinois Compiled Statutes 2605/7, and 415 Illinois Compiled Statutes 5/46 (2008). The purpose of the ordinance is to establish an orderly and fair system whereby the operations, maintenance, and replacement costs incurred by the District in treating and disposing of the sewage, industrial wastes, and other wastes generated by each User is charged to that User for his or her use of the sewage collection and treatment facilities of the District as required by the Federal Water Pollution Control Act Amendments of 1972 (P. L. 92-500) and the Clean Water Act of 1977 (P.L. 95-217) and the rules and regulations of the United States Environmental Protection Agency, promulgated pursuant thereto. The District computes user charge rates annually which are applied to flow, mass of biochemical oxygen demand (BOD), and mass of suspended solids (SS) released to the sewerage system for Industrial Users (IU) and Tax Exempt Users (TXE) (users who pay no ad valorem tax and all federal, state, and local governmental Users, but excluding publicly owned facilities performing local government functions which discharge solely domestic waste). The annual User Charge rate calculations are posted on the District's website and are most recently contained in Monitoring and Research Department Report No. 09-74, Calculation of 2010 User Charge Rates.

The Illinois Pollution Control Board (IPCB) recently requested an analysis of effect on user charge rates for IU and TXE that might result from various potential regulatory compliance scenarios currently being considered in R08-9 or in future anticipated rulemakings. In response to this request, sensitivity of the User Charge Rates to increased Operations, Maintenance, and Replacement (OM&R) Costs due to potential future regulatory compliance scenarios was undertaken. It should be noted that User Charge rates are only based on OM&R costs and can not be used to recover the initial capital costs required to install the additional treatment necessary to attain regulatory compliance in the following scenarios. The scenarios that were considered include:

1. Ultraviolet irradiation disinfection technology (UV Disinfection),
2. UV Disinfection and Filtration,
3. UV Disinfection with supplemental aeration and flow augmentation (DO Control),
4. UV disinfection and Filtration and DO Control,
5. Nutrient Removal Scenario 1 (0.5 mg/L Total P and 6-8 mg/L Total N)
6. Nutrient Removal Scenario 2 (0.1 mg/L Total P and 3 mg/L Total N)
7. UV Disinfection and Nutrient Removal Scenario 1,
8. UV Disinfection, DO Control and Nutrient Removal Scenario 1,
9. UV Disinfection and Nutrient Removal Scenario 2,
10. UV Disinfection, DO Control and Nutrient Removal Scenario 2,

OM&R Cost Increases are based on cost estimates for additional pollutant removal added to 2010 District budgeted amounts. User Charge Rate Calculations were based on using the increased OM&R costs associated with the increasing levels of wastewater treatment and 2009 operational data that were used in the calculation of the 2011 User Charge Rates. Any Disinfection and Filtration Costs were added directly to budgeted costs for Treatment. Nutrient removal costs were apportioned between Treatment, Solids Processing and Solids Utilization on a weighted basis. It should be noted that these estimates do not account for changes in ad valorem tax rates that may occur due to the regulatory compliance scenarios being considered as there was not sufficient time to add this complexity to the analysis. Changes in these rates would increase the credit to IU from ad valorem tax payments, thereby reducing their net user charge fees. Estimates of changes in ad valorem tax rates are considered in other portions of the District's submittal in response to IPCB requests.

Table 1 displays the Total OM&R costs and percent increase in User Charge Rates for IU and TXE for all of the scenarios listed above plus the current baseline scenario.

A. UV Disinfection Scenario

This scenario is based on implementation of UV disinfection at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. Implementation of this scenario would increase the OM&R costs by $22.1 million and would result in an increase in user charge rates of approximately 8 percent for both IU and TXE (Table 1). Table 2 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for the UV Disinfection Scenario, while Table 3 shows the impact on OM&R costs that result from this scenario.

B. UV Disinfection and Filtration Scenario

This scenario is based on implementation of UV disinfection with filtration at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. Implementation of this scenario would increase the OM&R costs by $31.7 million and would result in an increase in user charge rates of approximately 10 percent for both IU and TXE (Table 1). Table 4 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 5 shows the impact on OM&R costs that result from this scenario.

C. UV Disinfection with DO Control Scenario

This scenario is based on implementation of UV disinfection at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. In addition, the scenario also includes implementation of 18 additional supplemental aeration stations with flow augmentation in the North Shore Channel, the Little Calumet River and the South Fork of the South Branch of the Chicago River to meet the proposed dissolved oxygen standards in R08-9 as outlined in the testimony of David R. Zenz, AECOM Engineers. Implementation of this scenario would increase the OM&R costs by $29 million and would result in an increase in user charge rates of approximately 9 percent for both IU and TXE (Table 1). Table 6 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 7 shows the impact on OM&R costs that result from this scenario.

D. UV disinfection and Filtration and DO Control

This scenario is based on implementation of UV disinfection with filtration at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. In addition, the scenario also includes implementation of 18 additional supplemental aeration stations with flow augmentation in the North Shore Channel, the Little Calumet River and the South Fork of the South Branch of the Chicago River to meet the proposed dissolved oxygen standards in R08-9 as outlined in the testimony of David R. Zenz, AECOM Engineers. Implementation of this scenario would increase the OM&R costs by $38.6 million and would result in an increase in user charge rates of approximately 14 percent for both IU and TXE (Table 1). Table 8 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 9 shows the impact on OM&R costs that result from this scenario.

E. Nutrient Removal Scenario 1

This scenario is based on implementation of wastewater treatment at all of the District's WRPs except the Lemont WRP to meet an effluent limitation of 0.5 mg/L total P and 6 mg/L total N. The details of this scenario are discussed in other portions of the District's submittal in response to IPCB requests. Implementation of this scenario would increase the OM&R costs by $138.2 million and would result in an increase in user charge rates of approximately 52 percent for both IU and TXE (Table 1). Table 10 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 11 shows the impact on OM&R costs that result from this scenario.

F. Nutrient Removal Scenario 2

This scenario is based on implementation of wastewater treatment at all of the District's WRPs except the Lemont WRP to meet an effluent limitation of 0.1 mg/L total P and 3 mg/L total N. The details of this scenario are discussed in other portions of the District's submittal in response to IPCB requests. Implementation of this scenario would increase the OM&R costs by $365.2 million and would result in an increase in user charge rates of approximately 135 percent for both IU and TXE (Table 1). Table 12 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 13 shows the impact on OM&R costs that result from this scenario.

G. UV Disinfection and Nutrient Removal Scenario 1

This scenario is based on implementation of wastewater treatment at all of the District's WRPs except the Lemont WRP to meet an effluent limitation of 0.5 mg/L total P and 6 mg/L total N. The details of this scenario are discussed in other portions of the District's submittal in response to IPCB requests. This scenario also includes implementation of UV disinfection at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. Implementation of this scenario would increase the OM&R costs by $160.3 million and would result in an increase in user charge rates of approximately 59 percent for both IU and TXE (Table 1). Table 14 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 15 shows the impact on OM&R costs that result from this scenario.

H. UV Disinfection, DO Control and Nutrient Removal Scenario 1

This scenario is based on implementation of wastewater treatment at all of the District's WRPs except the Lemont WRP to meet an effluent limitation of 0.5 mg/L total P and 6 mg/L total N. The details of this scenario are discussed in other portions of the District's submittal in response to IPCB requests. This scenario also includes implementation of UV disinfection at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. In addition, the scenario also includes implementation of 18 additional supplemental aeration stations with flow augmentation in the North Shore Channel, the Little Calumet River and the South Fork of the South Branch of the Chicago River to meet the proposed dissolved oxygen standards in R08-9 as outlined in the testimony of David R. Zenz, AECOM Engineers. Implementation of this scenario would increase the OM&R costs by $167.2 million and would result in an increase in user charge rates of approximately 61 percent for both IU and TXE (Table 1). Table 16 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 17 shows the impact on OM&R costs that result from this scenario.

I. UV Disinfection and Nutrient Removal Scenario 2

This scenario is based on implementation of wastewater treatment at all of the District's WRPs except the Lemont WRP to meet an effluent limitation of 0.1 mg/L total P and 3 mg/L total N. The details of this scenario are discussed in other portions of the District's submittal in response to IPCB requests. This scenario also includes implementation of UV disinfection at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. Implementation of this scenario would increase the OM&R costs by $387.1 million and would result in an increase in user charge rates of approximately 143 percent for both IU and TXE (Table 1). Table 18 shows the 2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 19 shows the impact on OM&R costs that result from this scenario.

J. UV Disinfection, DO Control and Nutrient Removal Scenario 2

This scenario is based on implementation of wastewater treatment at all of the District's WRPs except the Lemont WRP to meet an effluent limitation of 0.1 mg/L total P and 3 mg/L total N. The details of this scenario are discussed in other portions of the District's submittal in response to IPCB requests. This scenario also includes implementation of UV disinfection at the Stickney, Calumet and North Side WRPs to meet the proposed fecal coliform effluent limitations currently before the IPCB in R08-9. In addition, the scenario also includes implementation of 18 additional supplemental aeration stations with flow augmentation in the North Shore Channel, the Little Calumet River and the South Fork of the South Branch of the Chicago River to meet the proposed dissolved oxygen standards in R08-9 as outlined in the testimony of David R. Zenz, AECOM Engineers. Implementation of this scenario would increase the OM&R costs by $394 million and would result in an increase in user charge rates of approximately 146 percent for both IU and TXE (Table 1). Table 20 shows the

2011 User Charge Rates in more detail for the baseline scenario (current level of wastewater treatment) and the rates that would result for this scenario, while Table 21 shows the impact on OM&R costs that result from this scenario.

Table 1: Summary of Impacts of Regulatory Compliance Scenarios on Total OM&R Costs and User Charge Rate Increases

Treatment Level	Total Operations, Maintenance & Replacement Cost (Millions)	Percent User Charge Rate Increase for Large-Commercial and Tax-Exempt Users
No Change in Treatment Level	$374	0%
UV Disinfection	$396	8%
UV Disinfection & DO Control	$403	9%
UV Disinfection & Filtration	$405	10%
UV Disinfection & Filtration & DO Control	$412	14%
Nutrient Removal Scenario 1	$512	52%
Nutrient Removal Scenario 1 & UV Disinfection	$534	59%
Nutrient Removal Scenario 1 & UV Disinfection & DO Control	$541	61%
Nutrient Removal Scenario 2	$739	135%
Nutrient Removal Scenario 2 & UV Disinfection	$761	143%
Nutrient Removal Scenario 2 & UV Disinfection & DO Control	$768	146%

Table 2: User Charge Rates Using the 2011 Rate Calculations Template With UV Disinfection Costs

IU	Cost	Parameter Total	2011 Rate W/Disinfect.	2011 Rate	% Change
Volume	$ 4,466,700	16,905	$ 264.22	$ 243.99	**8.29%**
BOD	$ 37,825,542	141,149	$ 267.98	$ 247.48	**8.28%**
SS	$ 7,004,530	33,313	$ 210.26	$ 194.18	**8.28%**
TXE					
Volume	$ 3,123,368	11,545	$ 270.54	$ 250.31	**8.08%**
BOD	$ 5,788,761	21,097	$ 274.39	$ 253.89	**8.07%**
SS	$ 8,786,824	40,814	$ 215.29	$ 199.21	**8.07%**

Table 3: Impact on OM&R Costs From UV Disinfection

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Disinfection	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus Disinfection Only	76,800,000	98,900,000	**$22,100,000**
3000 Solids Processing	36,400,000	36,400,000	
4000 Flood and Pollution Control	32,110,296	32,110,296	
5000 Solids Utilization	25,900,000	25,900,000	
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$359,800,852	**$22,100,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$396,202,175	**$22,100,000**

Table 4: User Charge Rate Comparison Using the 2011 Rate Calculation Template With UV Disinfection and Filtration Costs

IU	Cost	Parameter Total	2011 Rate Modified	2011 Rate	**% Change**
Volume	$ 4,615,351	16,905	$ 273.02	$ 243.99	**11.90%**
BOD	$ 39,083,554	141,149	$ 276.90	$ 247.48	**11.89%**
SS	$ 7,237,679	33,313	$ 217.26	$ 194.18	**11.89%**
TXE					
Volume	$ 3,224,887	11,545	$ 279.33	$ 250.31	**11.59%**
BOD	$ 5,976,789	21,097	$ 283.30	$ 253.89	**11.58%**
SS	$ 9,072,474	40,814	$ 222.29	$ 199.21	**11.58%**

Table 5: Impact on OM&R Costs From UV Disinfection and Filtration

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Dis.& Filt.	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus Disinfection & Filtration	76,800,000	108,500,000	**$31,700,000**
3000 Solids Processing	36,400,000	36,400,000	
4000 Flood and Pollution Control	32,110,296	32,110,296	
5000 Solids Utilization	25,900,000	25,900,000	
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$369,400,852	**$31,700,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$405,802,175	**$31,700,000**

Table 6: User Charge Rates Using the 2011 Rate Calculations Template With UV Disinfection and DO Control Costs

IU	Cost	Parameter Total	2011 Rate Modified	2011 Rate	% Change
Volume	$ 4,573,534	16,905	$ 270.54	$ 243.99	**10.88%**
BOD	$ 38,729,738	141,149	$ 274.39	$ 247.48	**10.87%**
SS	$ 7,172,058	33,313	$ 215.29	$ 194.18	**10.87%**
TXE					
Volume	$ 3,196,329	11,545	$ 276.86	$ 250.31	**10.61%**
BOD	$ 5,923,906	21,097	$ 280.79	$ 253.89	**10.60%**
SS	$ 8,992,075	40,814	$ 220.32	$ 199.21	**10.60%**

Table 7: Impact on OM&R Costs From UV Disinfection and DO Control

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Disinfection	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus Disinfection Only	76,800,000	98,900,000	**$22,100,000**
3000 Solids Processing	36,400,000	36,400,000	
4000 Flood and Pollution Control Plus DO Control	32,110,296	39,010,296	**$6,900,000**
5000 Solids Utilization	25,900,000	25,900,000	
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$366,700,852	**$29,000,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$403,102,175	**$29,000,000**

Table 8: User Charge Rates Using the 2011 Rate Calculations Template With UV Disinfection, Filtration and DO Control Costs

IU		Cost	Parameter Total		2011 Rate Modified		2011 Rate	% Change
Volume	$	4,721,899	16,905	$	279.32	$	243.99	**14.48%**
BOD	$	39,987,751	141,149	$	283.30	$	247.48	**14.47%**
SS	$	7,405,208	33,313	$	222.29	$	194.18	**14.48%**
TXE								
Volume	$	3,297,649	11,545	$	285.63	$	250.31	**14.11%**
BOD	$	6,111,936	21,097	$	289.71	$	253.89	**14.11%**
SS	$	9,277,727	40,814	$	227.32	$	199.21	**14.11%**

Table 9: Impact on OM&R Costs From UV Disinfection, Filtration and DO Control Costs

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Dis,DO& Filt	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus Disinfection & Filtration	76,800,000	108,500,000	**$31,700,000**
3000 Solids Processing	36,400,000	36,400,000	
4000 Flood and Pollution Control Plus DO Control	32,110,296	39,010,296	**$6,900,000**
5000 Solids Utilization	25,900,000	25,900,000	
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$376,300,852	**$38,600,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$412,702,175	**$38,600,000**

Table 10: User Charge Rate Comparison Using the 2011 Rate Calculation Template With Nutrient Removal Scenario 1

IU	Cost	Parameter Total	2011 Rate W/NR High	2011 Rate	% Change
Volume	$ 6,263,118	16,905	$ 370.49	$ 243.99	51.85%
BOD	$ 53,039,627	141,149	$ 375.77	$ 247.48	51.84%
SS	$ 9,821,627	33,313	$ 294.83	$ 194.18	51.83%
TXE					
Volume	$ 4,350,202	11,545	$ 376.80	$ 250.31	50.53%
BOD	$ 8,062,754	21,097	$ 382.18	$ 253.89	50.53%
SS	$ 12,238,239	40,814	$ 299.85	$ 199.21	50.52%

Table 11: Impact on OM&R Costs From Nutrient Removal Scenario 1

Costs Apportioned Between Treatment, Solids Processing and Solids Utilization

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus NRS 1	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment	76,800,000	153,103,091	**76,303,091**
3000 Solids Processing	36,400,000	72,564,486	**36,164,486**
4000 Flood and Pollution Control	32,110,296	32,110,296	
5000 Solids Utilization	25,900,000	51,632,423	**25,732,423**
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$475,900,852	
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$512,302,175	**$138,200,000**

Cost Apportionment

2000 Treatment	76,800,000
3000 Solids Processing	36,400,000
5000 Solids Utilization	25,900,000
Total	139,100,000
Apportionment Percent	
Treatment	0.55
Solids Processing	0.26
Solids Utilization	0.19
Total	1.00
Apportionment Nutrient Removal	
Total Cost for High Level Nut. Removal	
Treatment	76,303,091
Solids Processing	36,164,486
Solids Utilization	25,732,423
Total Cost for High-Level Nut. Removal	138,200,000
Treatemnt	153,103,091
Solids Processing	72,564,486
Solids Utilization	51,632,423
Total	277,300,000

Table 12: User Charge Rate Comparison Using the 2011 Rate Calculation Template With Nutrient Removal Scenario 2

IU	Cost	Parameter Total	2011 Rate W/NR Low	2011 Rate	% Change
Volume	$ 9,775,471	16,905	**$ 578.26**	$ 243.99	**137.00%**
BOD	$ 82,782,004	141,149	**$ 586.49**	$ 247.48	**136.98%**
SS	$ 15,329,984	33,313	**$ 460.18**	$ 194.18	**136.99%**
TXE					
Volume	$ 6,748,907	11,545	**$ 584.57**	$ 250.31	**133.54%**
BOD	$ 12,508,229	21,097	**$ 592.89**	$ 253.89	**133.52%**
SS	$ 18,986,902	40,814	**$ 465.21**	$ 199.21	**133.53%**

Table 13: Impact on OM&R Costs From Nutrient Removal Scenario 2

Costs Apportioned Between Treatment, Solids Processing and Solids Utilization

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus NRS 2	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment	76,800,000	278,434,508	**201,634,508**
3000 Solids Processing	36,400,000	131,966,355	**95,566,355**
4000 Flood and Pollution Control	32,110,296	32,110,296	
5000 Solids Utilization	25,900,000	93,899,137	**67,999,137**
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$702,900,852	**365,200,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$739,302,175	**365,200,000**

Table 14: User Charge Rate Comparison Using the 2011 Rate Calculation Template With UV Disinfection and Nutrient Removal Scenario 1 Co

IU		Cost	Parameter Total		2011 Rate Modified		2011 Rate	% Change
Volume	$	6,605,102	16,905	$	390.72	$	243.99	**60.14%**
BOD	$	55,935,675	141,149	$	396.29	$	247.48	**60.13%**
SS	$	10,358,181	33,313	$	310.94	$	194.18	**60.13%**
TXE								
Volume	$	4,583,754	11,545	$	397.03	$	250.31	**58.62%**
BOD	$	8,495,613	21,097	$	402.69	$	253.89	**58.61%**
SS	$	12,895,609	40,814	$	315.96	$	199.21	**58.61%**

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Table 15: Impact on OM&R Costs From UV Disinfection and Nutrient Removal
Scenario 1

Nutrient Costs Apportioned Between Treatment, Solids Processing and Solids Utilization

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Dis.,NRS 1	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus App. Nut. And Tot. Disinfect Cost	76,800,000	175,203,091	**$98,403,091**
3000 Solids Processing	36,400,000	72,564,486	**$36,164,486**
4000 Flood and Pollution Control	32,110,296	32,110,296	
5000 Solids Utilization	25,900,000	51,632,423	**$25,732,423**
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$498,000,852	**$160,300,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$534,402,175	**$160,300,000**

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Cost Apportionment	
2000 Treatment	76,800,000
3000 Solids Processing	36,400,000
5000 Solids Utilization	25,900,000
Total	139,100,000
Apportionment Percent	
Treatment	0.55
Solids Processing	0.26
Solids Utilization	0.19
Total	1.00
Apportionment Nutrient Removal	
Total Cost for High Level Nut. Removal	
Treatment	76,303,091
Solids Processing	36,164,486
Solids Utilization	25,732,423
Total Cost for High-Level Nut. Removal	138,200,000
Treatemnt + Total Disinfection Cost	175,203,091
Solids Processing	72,564,486
Solids Utilization	51,632,423
Total	299,400,000

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Table 16: User Charge Rate Comparison Using the 2011 Rate Calculation Template
With UV Disinfection, DO Control and Nutrient Removal Scenario 1 Costs

IU	Cost	Parameter Total	2011 Rate Modified	2011 Rate	% Change
Volume	$ 6,711,937	16,905	$ 397.04	$ 243.99	**62.73%**
BOD	$ 56,837,688	141,149	$ 402.68	$ 247.48	**62.71%**
SS	$ 10,525,709	33,313	$ 315.96	$ 194.18	**62.72%**
TXE					
Volume	$ 4,656,716	11,545	$ 403.35	$ 250.31	**61.14%**
BOD	$ 8,630,429	21,097	$ 409.08	$ 253.89	**61.13%**
SS	$ 13,100,862	40,814	$ 320.99	$ 199.21	**61.13%**

Table 17: Impact on OM&R Costs From UV Disinfection, DO Control, and Nutrient Removal Scenario 1 Costs

Nutrient Costs Apportioned Between Treatment, Solids Processing and Solids Utilization

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Dis,DO,NRS 1	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus App. Nut. And Tot. Disinfect Cost	76,800,000	175,203,091	**$98,403,091**
3000 Solids Processing	36,400,000	72,564,486	**$36,164,486**
4000 Flood and Pollution Control Plus DO Control Costs	32,110,296	39,010,296	**$6,900,000**
5000 Solids Utilization	25,900,000	51,632,423	**$25,732,423**
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$504,900,852	**$167,200,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$541,302,175	**$167,200,000**

Cost Apportionment	
2000 Treatment	76,800,000
3000 Solids Processing	36,400,000
5000 Solids Utilization	25,900,000
Total	139,100,000
Apportionment Percent	
Treatment	0.55
Solids Processing	0.26
Solids Utilization	0.19
Total	1.00
Apportionment Nutrient Removal	
Total Cost for High Level Nut. Removal	
Treatment	76,303,091
Solids Processing	36,164,486
Solids Utilization	25,732,423
Total Cost for High-Level Nut. Removal	138,200,000
Treatemnt + Total Disinfection Cost ($22.1 Million)	175,203,091
Solids Processing	72,564,486
Solids Utilization	51,632,423
Total	299,400,000

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Table 18: User Charge Rate Comparison Using the 2011 Rate Calculation Template With UV Disinfection and Nutrient Removal Scenario 2 Co

IU		Cost	Parameter Total		2011 Rate Modified		2011 Rate	% Change
Volume	$	10,114,591	16,905	$	598.32	$	243.99	**145.22%**
BOD	$	85,654,028	141,149	$	606.83	$	247.48	**145.21%**
SS	$	15,861,905	33,313	$	476.15	$	194.18	**145.21%**
TXE								
Volume	$	6,980,503	11,545	$	604.63	$	250.31	**141.55%**
BOD	$	12,937,499	21,097	$	613.24	$	253.89	**141.54%**
SS	$	19,638,595	40,814	$	481.17	$	199.21	**141.54%**

sts

Table 19: Impact on OM&R Costs From UV Disinfection & Nutrient Removal Scenario 2

Nutrient Costs Apportioned Between Treatment, Solids Processing and Solids Utilization

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Dis.,NRS 2	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus App. Nut. And Tot. Disinfect Cost	76,800,000	300,354,508	**$223,554,508**
3000 Solids Processing	36,400,000	131,966,355	**$95,566,355**
4000 Flood and Pollution Control	32,110,296	32,110,296	
5000 Solids Utilization	25,900,000	93,899,137	**$67,999,137**
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$724,820,852	**$387,120,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$761,222,175	**$387,120,000**

2000 Treatment	76,800,000
3000 Solids Processing	36,400,000
5000 Solids Utilization	25,900,000
	139,100,000
Apportionment Percent	
Treatment	0.55
Solids Processing	0.26
Solids Utilization	0.19
	1.00
Apportionment Nutrient Removal	
Total Cost for High Level Nut. Removal	365,200,000
Treatment	201,634,508
Solids Processing	95,566,355
Solids Utilization	67,999,137
Treatemnt+ Total Disinfection Cost	300,534,508
Solids Processing	131,966,355
Solids Utilization	93,899,137
	526,400,000
Disinfection Cost	22,100,000

Table 20: User Charge Rate Comparison Using the 2011 Rate Calculation Template
With UV Disinfection, Nutrient Removal Scenario 2 and DO Control Costs

IU	Cost	Parameter Total	2011 Rate Modified	2011 Rate	% Change
Volume	$ 10,221,425	16,905	$ 604.64	$ 243.99	**147.81%**
BOD	$ 86,558,224	141,149	$ 613.24	$ 247.48	**147.79%**
SS	$ 16,029,433	33,313	$ 481.18	$ 194.18	**147.80%**
TXE					
Volume	$ 7,053,464	11,545	$ 610.95	$ 250.31	**144.08%**
BOD	$ 13,072,645	21,097	$ 619.64	$ 253.89	**144.06%**
SS	$ 19,843,845	40,814	$ 486.20	$ 199.21	**144.07%**

Table 21: Impact on OM&R Costs From UV Disinfection, Nutrient Removal Scenario 2 & DO Control Costs

Nutrient Costs Apportioned Between Treatment, Solids Processing and Solids Utilization

Budgeted Corporate Fund Programs Directly Related to OM&R Costs	2010 Budget	2010 Plus Dis.,NRS 2	Increase
1000 Collection	$60,100,000	$60,100,000	
2000 Treatment Plus App. Nut And Tot. Disinfect Costs	76,800,000	300,354,508	**$223,554,508**
3000 Solids Processing	36,400,000	131,966,355	**$95,566,355**
4000 Flood and Pollution Control Plus DO Control Costs	32,110,296	39,010,296	**$6,900,000**
5000 Solids Utilization	25,900,000	93,899,137	**$67,999,137**
7000 General Support	106,390,556	106,390,556	
Sub-Total	$337,700,852	$731,720,852	**$394,020,000**
Annuity and Benefit Fund	30,671,702	30,671,702	
Reserve Claim Fund	4,963,787	4,963,787	
Construction & Working Cash Fund	765,833	765,833	
Total OM&R Cost	$374,102,175	$768,122,175	**$394,020,000**

ITEM 7A

ITEM 7A

STATUS OF FEDERAL AND STATE NUTRIENT REDUCTION REQUIREMENTS FOR MWRD

There are a number of pending Federal and State initiatives that may lead to nutrient reduction requirements for the MWRD's wastewater treatment plants. Some of these initiatives are based on water quality concerns, and result from the Clean Water Act requirements that States (with EPA review and approval) set water quality standards and then develop and implement measures to attain those standards, through Total Maximum Daily Loads (TMDLs) and NPDES permits. Other initiatives are based on technology-based requirements in the Clean Water Act.

As to water quality, Section 303 of the Act requires States to establish numeric water quality standards as needed to protect designated uses. As to nutrients specifically, EPA has issued guidance to the States as to various approaches for developing nutrient standards. That guidance includes recommended water quality criteria for phosphorus (P), nitrogen (N) and other nutrient-related parameters. The recommended criteria levels are extremely stringent – for example, the levels for the specific ecoregion that includes the CAWS (Ecoregion 54) are 0.073 mg/L for P and 2.95 mg/L for N. (These levels are specified in the following EPA guidance document: http://water.epa.gov/scitech/swguidance/waterquality/standards/criteria/aqlife/pollutants/nutrient/upload/2007_09_27_criteria_nutrient_ecoregions_rivers_rivers_6.pdf at 17).

Significant scientific and practical concerns were raised concerning the scientific basis for these EPA recommended nutrient levels. As a result, those guidance levels have not been widely used by States. State agencies have also found that developing their own nutrient criteria is time-consuming and resource-intensive. As a result, efforts in this area have proceeded slowly. In the last few years, though, nutrient criteria development efforts have moved forward in several States.

In some States, environmental groups have filed papers indicating their intent to sue EPA over the pace of the nutrient standards development activities. This has occurred, for example, in Wisconsin, Kansas and Florida. In Florida, the environmental groups proceeded to file a lawsuit, and this led to a settlement with EPA, under which EPA agreed to issue Federal numeric nutrient criteria for the waters in the State of Florida. These criteria were issued in final form on November 14, 2010, as to lakes and rivers/streams in Florida (http://water.epa.gov/lawsregs/rulesregs/florida_index.cfm). (Criteria for coastal and estuarine waters will be issued later.) The criteria levels for rivers/streams range from 0.06 mg/L to 0.49 mg/L for P and from 0.67 mg/L to 1.87 mg/L for N. (Criteria for lakes are generally lower.) There is also a downward adjustment, to make the criteria more stringent, if the waterbody at issue is upstream of a lake, based on "downstream protection values." Several legal challenges to the final rules have been filed in Federal court. In Wisconsin, final standards for phosphorus have been issued by the State, and are awaiting EPA approval (http://dnr.wi.gov/org/nrboard/2010/June/06-10-3A4.pdf and http://dnr.wi.gov/org/nrboard/2010/June/06-10-NRB-Minutes.pdf). The criteria levels for P are: 0.1 mg/L for large rivers and streams, 0.075 mg/L for all other rivers and streams, and lower levels for lakes.

In addition to those efforts by States and EPA to set nutrient standards for specific waters, there is also attention being paid to nutrient issues on a broader level, for the Gulf of Mexico and the Mississippi-Atchafalaya River Basin (which includes the Chicago Area Waterways System). In 2008, EPA issued an Action Plan (http://water.epa.gov/type/watersheds/named/msbasin/actionplan.cfm), which established a goal of reducing aggregate N and P loadings to the Gulf by 45%, to help address concerns over the hypoxic zone in the Gulf. Several other reports have been issued since, which contain specific recommendations as to reductions in N and P loadings throughout the Basin. (For example, the National Research Council issued this report in 2010: http://dels.nas.edu/Report/Improving-Water-Quality-Mississippi/13029 .) Also, a coalition of environmental groups has submitted a petition to EPA, asking that the Agency establish Federal nutrient water quality standards for all waters in the Gulf/Mississippi

River Basin that do not currently have such standards, and then to establish Federal TMDLs for those waters that do not meet those standards (http://www.elpc.org/documents/NutrientPetitionFINAL.pdf). The TMDLs would establish specific wasteload allocations for sources to those waters, so that nutrient levels in those waters would be reduced to attain the Federal standards.

Along with those initiatives to impose nutrient control requirements on the basis of water quality standards, there are also activities underway to impose nutrient control requirements under the technology-based provisions of the Clean Water Act. Under the Act, municipal sewage treatment plants are required to comply with effluent limits that are based on the pollutant levels that can be attained by "secondary treatment." Those limits are for the parameters biochemical oxygen demand (BOD), suspended solids (SS) and pH. A coalition of environmental groups has submitted a petition to EPA, asking that the Agency revise the definition of "secondary treatment" to include nutrient removal, so that municipal plants would also have to comply with limits for N and P. The petition (http://www.iawpca.org/about/govt_affairs/2007-11-27nrdcprt.pdf) included statements to the effect that limits of 0.3 mg/L for P and 3.0 mg/L for N would be "consistently attainable using current technology." EPA has not yet taken action on the petition.

In Illinois, nutrient reduction requirements were first imposed in 2006, when Illinois EPA proposed, and the Board adopted, a phosphorus standard for new and expanded discharges into General Use waters (35 Ill. Adm. Code 304.123(g)). That standard provides a monthly average permit limit of 1 mg/L for municipal plants with average flows of 1 million gallons per day and other treatment plants with phosphorus effluent loads of 25 pounds per day or more. Recently, Illinois EPA has begun discussions with stakeholders about developing additional nutrient reduction requirements for the State. Several meetings of the stakeholder group have been held. A meeting regarding water quality standards issues has been scheduled for January 6, 2011. Technology-based requirements have been and will be discussed as well. Illinois EPA has stated that it considers the "limit of technology" to be levels of 0.1 – 0.5 mg/L for P and 1 – 3 mg/L for N (http://www.epa.state.il.us/water/nutrient/presentations/marcia_willhite.pdf at 19). It is expected that in the near future, Illinois EPA will prepare several nutrient regulatory options to present to the Board.

ITEM 7B

ITEM 7B

ESTIMATED COMPLIANCE COSTS FOR NUTRIENT REMOVAL

Rudimentary, order-of-magnitude cost estimates have been developed for nutrient removal at six of the District's seven water reclamation plants (WRP). The Lemont WRP was not included, as it is planned to be converted into a wastewater pumping station. Cost estimates are provided for two sets of potential effluent concentration limits for total nitrogen (TN) and total phosphorus (TP):

- Nutrient Removal Standards Scenario #1 (TP = 0.5 mg/L; TN = 6 to 8 mg/L)
- Nutrient Removal Standards Scenario #2 (TP = 0.1 mg/L; TN = 3 mg/L)

Nutrient Removal Standards Scenario #1

Under the District's master planning studies for the Calumet and North Side Water Reclamation Plants (WRPs), conceptual level cost estimates were performed for various nutrient removal processes, as a planning tool in the event that nutrient limits are imposed. The cost estimates assume hypothetical effluent limits of 0.5 mg/L for TP and between 6 to 8 mg/L for TN. These cost estimates were used to derive capital and annual operation and maintenance (O&M) costs on a flow basis (i.e. dollars per million gallons of sewage treated). Costs for the other four WRPs were extrapolated from these ratios. The total estimated capital and annual costs for all six WRPs are listed below. Costs are in year 2008 dollars.

- Estimated Capital Costs $2.8 billion
- Estimated Annual O&M Costs $138.2 million/year

Refer to Attachment 1 for further details with regard to this cost estimate. Also, note that this cost estimate was previously included in John Mastracchio's pre-filed testimony to the IPCB. Refer to Exhibit 159 (submitted at IPCB hearings on October 28, 2008) and Exhibit 223 (submitted at IPCB hearings on March 3, 2009).

Nutrient Removal Standards Scenario #2

A rudimentary, order-of-magnitude cost estimate was generated for meeting effluent limits of 0.1 mg/L for TP and 3 mg/L for TN, simultaneously. Cost information was obtained from the U.S. Environmental Protection Agency's (USEPA) report entitled "Municipal Nutrient Removal Reference Document" (September 2008). The USEPA's report contains unit costs for both capital and annual O&M costs for the aforementioned TP and TN limits. These unit costs were multiplied by the design average flows of the District's six WRPs. The total estimated capital and annual costs for all six WRPs are listed below. The unit costs in the USEPA report are in year 2007 dollars, and the cost estimate below is in year 2007 dollars, as well. Note that costs for scenario #1, above, are expressed in year 2008 dollars, to be consistent with previous testimony. Refer to Attachment 2 for further details about the cost estimate for scenario #2.

- Estimated Capital Costs $5.0 billion

- Estimated Annual O&M Costs $365.2 million/year

As a check, a capital cost estimate was also developed based on a document by O'Brien & Gere, entitled "Public Commentary - Submitted to the Science Advisory Board - Hypoxia Advisory Panel - Draft Advisory Report" dated September 20, 2007. This document was previously provided to the IPCB at the hearing of October 28, 2010 (Exhibit 166). This document provides an average unit construction cost of $8.20 per gallon per day (gpd) to meet TP and TN limits based on case studies of actual plants in the Chesapeake Bay area. Refer to the document for the actual TP and TN effluent limits, which vary between the plants. Multiplying the unit construction cost by the design average flows of the District's six WRPs would yield an estimated construction cost of $16 billion in year 2006/2007 dollars. Refer to Attachment 3 for more details.

For the purpose of assessing the economic impacts of the costs to meet the effluent limits of scenario #2, the capital and O&M cost estimates based on the USEPA report were used. The economic impacts are presented elsewhere in this submittal to the IPCB.

Implementation Schedule

The following implementation schedule was developed for use in assessing economic impacts of the costs to comply with either nutrient removal scenario. Owing to the extremely large and unprecedented scale that nutrient removal would be implemented at three of the District's WRPs, pilot testing would be necessary to identify the appropriate process and develop design criteria.

- Development of pilot testing protocol, and design and construction of pilot scale equipment: 2013 through 2014
- Pilot testing: 2015 through 2016
- Full-scale Design: 2017 through 2019
- Construction: 2020 through 2023

The above schedule includes a total of seven years for design and construction of the full-scale facilities. As a comparison, construction of new primary settling tanks and grit removal facilities is currently taking place at the Calumet WRP. The construction cost is approximately $229 million. It is estimated that the duration of design and construction will be 7 years. The design commenced in October 2005, and completion of construction is anticipated in November 2012.

References

CTE|AECOM, “Master Plan – North Side Water Reclamation Plant”, June 2007

Metcalf & Eddy|AECOM, “Final Project Report”, Plant Process Needs Feasibility Study and Master Plan for the Calumet Water Reclamation Plant, April 2006

O’Brien & Gere, “Public Commentary - Submitted to the Science Advisory Board - Hypoxia Advisory Panel - Draft Advisory Report”, September 20, 2007

USEPA, “Municipal Nutrient Removal Reference Document”, EPA 832-R-08-006, September 2008

Attachment 1

Metropolitan Water Reclamation District of Greater Chicago
Engineering Department
Process Facilities Division

December 22, 2010

Rudimentary, Order-of-Magnitude Cost Estimates for Nutrient Removal at District Water Reclamation Plants

Nutrient Removal Standards Scenario #1: TP = 0.5 mg/L and TN = 6 - 8 mg/L

			Capital Cost		Annual M&O			TP Limit	TN limit
Plant	DMF (MGD)	DAF (MGD)	(Calculation)	(Rounded)	(Calculation)	(Rounded)	Reference	(mg/L)	(mg/L)
Stickney	1,440	1,200	$ 1,665,851,016	$ 1,666,000,000	$ 99,508,056	$ 100,000,000	3, 6	0.5	6 - 8
Calumet	430	354	$ 604,920,135	$ 605,000,000	$ 29,354,877	$ 29,000,000	2	0.5	6 - 8
North Side	450	333	$ 408,100,930	$ 408,000,000	$ 4,680,006	$ 4,700,000	1	0.5	6 - 8
Kirie	110	72	$ 83,139,642	$ 83,000,000	$ 1,011,893	$ 1,000,000	4, 5	0.5	6 - 8
Egan	50	30	$ 37,790,746	$ 38,000,000	$ 2,487,701	$ 2,500,000	4, 6	0.5	6 - 8
Hanover	22	12	$ 16,627,928	$ 17,000,000	$ 995,081	$ 1,000,000	4, 6	0.5	6 - 8
Total =	2,502	2,001	$ 2,816,430,398	$ 2,817,000,000	$ 138,037,614	$ 138,200,000			

General Notes:

Costs have been converted to year 2008 dollars by using the Engineering News Record Construction Cost Index.

The Lemont Water Reclamation Plant is not included, as it is planned to be converted to a sewage pumping station.

Reference Notes:

1- North Side WRP Master Plan (04-014-2P) Technical Memorandum 8. Refer to p. 8-90 and Appendix 8S.
This is the selected alternative for year 2020 (TP = 0.5 mg/L, TN = 6 - 8 mg/L)
This includes filtration and low level pump station.

2- Based on Calumet WRP Master Plan (97-259-2M) Final Report (April 2006) and Technical Memorandum-1WQ (Final, dated 8/26/05)
The Master Plan estimates the cost for chemical P and biological N removal in order to obtain TP = 1 mg/L, TN = 6 - 8 mg/L (no filtration included).
In order to achieve TP = 0.5 mg/L, costs for filtration & a low-lift pump station were added (source: Technical Memorandum-1WQ).

3- Average capital cost per MG (DMF) between North Side and Calumet estimates (this includes construction of filters and low-lift pump station)

NSWRP: $/MG (DMF) =	$	906,891	(TP = 0.5 mg/L, TN = 6-8 mg/L)
CWRP: $/MG (DMF) =	$	1,406,791	(TP = 0.5 mg/L, TN = 6-8 mg/L)
Average: $/MG (DMF) =	$	1,156,841	(TP = 0.5 mg/L, TN = 6-8 mg/L)

4- Capital cost per MG (DMF) from Calumet WRP Master Plan Final Project Report, April 2006 (i.e. does not include construction of filters).
The Calumet WRP Master Plan estimates the cost for chemical P and biological N removal in order to obtain TP = 1 mg/L, TN = 6 - 8 mg/L.
This value is used to estimate Kirie, Egan, and Hanover Park, because they already have filters.
This assumes that the current filters at Kirie, Egan, and Hanover Park are adequate to achieve TP = 0.5 mg/L.

CWRP cost, without filters =	$	325,000,419
CWRP: $/MG (DMF) =	$	755,815

5- Total annual M&O costs per MG (DAF) for North Side (i.e. a non-sludge-processing WRP)
NSWRP: $/MG (DAF) = $ 14,054

6- Total annual M&O costs per MG (DAF) for Calumet (i.e. a sludge processing WRP)
CWRP: $/MG (DAF) = $ 82,923

Attachment 2

Metropolitan Water Reclamation District of Greater Chicago
Engineering Department
Process Facilities Division

December 22, 2010

Rudimentary, Order-of-Magnitude Cost Estimates for Nutrient Removal at District Water Reclamation Plants

Nutrient Removal Standards Scenario #2: TP = 0.1 mg/L and TN = 3 mg/L

		Capital Cost		Annual O&M	
Plant	DAF (MGD)	Unit Cost ($/gpd)	Capital Cost	Unit Cost ($/MG treated)	Annual O&M
Stickney	1200	$2.50	$ 3,000,000,000	$500	$ 219,000,000
Calumet	354	$2.50	$ 885,000,000	$500	$ 64,605,000
North Side	333	$2.50	$ 832,500,000	$500	$ 60,772,500
Kirie	72	$2.50	$ 180,000,000	$500	$ 13,140,000
Egan	30	$2.50	$ 75,000,000	$500	$ 5,475,000
Hanover	12	$2.50	$ 30,000,000	$500	$ 2,190,000
Total =	2001		$ 5,002,500,000		$ 365,182,500

Rounded to $5.00 billion

Rounded to $365.2 million/year

Notes:

Source of unit costs: USEPA's Municipal Nutrient Removal Reference Document (September 2008)

The costs provided in the USEPA report are "planning-level cost estimates", as stated on page 4-19.

The costs are in year 2007 dollars.

The unit costs for capital and annual O&M costs are taken from the cost curves in Figures 4-21 and 4-22.

The scenario that is used for this estimate is five-stage Bardenpho with chemical plus tertiary filter, for target effluent concentrations of total nitrogen (TN) = 3 mg/L and total phosphorus (TP) = 0.1 mg/L.

The cost curves cover a flow range of 1 MGD to 10 MGD. Ten MGD was selected for this estimate.

For capital costs, the unit cost is $2.50/gpd, based on Figure 4-21.

For annual O&M costs, the unit cost is approximately $500/MG treated, based on Figure 4-22.

The Lemont Water Reclamation Plant is not included, as it is planned to be converted to a sewage pumping station.

Attachment 3

Metropolitan Water Reclamation District of Greater Chicago
Engineering Department
Process Facilities Division

December 22, 2010

Rudimentary, Order-of-Magnitude Cost Estimates for Nutrient Removal at District Water Reclamation Plants

Based on Document by O'Brien & Gere *

Plant	DAF (MGD)	Unit Cost ($/gpd)	Estimate of Capital Cost	
Stickney	1,200			
Calumet	354			
North Side	333			
Kirie	72			
Egan	30			
Hanover	12			
Total =	2,001	$8.20	$16,408,200,000	→ Rounded to $16 billion

Notes:

* The unit cost of $8.20/gpd is from "Public Commentary - Submitted to the Science Advisory Board - Hypoxia Advisory Panel - Draft Advisory Report", by O'Brien & Gere, dated September 20, 2007.

The unit cost of $8.20 is based on case studies of actual plants in the Chesapeake Bay area. Refer to the above referenced document for the actual TP and TN concentration limits, which vary between the plants.

Costs are in year 2006/2007 dollars, per the above referenced document by O'Brien & Gere.

The Lemont Water Reclamation Plant is not included in this cost estimate, as it is planned to be converted to a sewage pumping station.

ITEM 7C

ITEM 7C

FUNDING SOURCES FOR NUTRIENT REMOVAL

The District is not aware of any special funding sources for nutrient removal, and the current funding limitations under the tax cap prohibit the District from funding such a program. The District's funding requirements for 2011 are at the maximum allowable under the tax cap for the operating funds. The District's capital improvements program including master plan projects is estimated to consume all of the District's non-referendum bonding authority through 2024. While some disinfection projects may be eligible under the SRF program, the state has limited funding available; therefore, it is assumed that SRF funding for those projects would be in lieu of currently planned projects, not in addition to those planned projects.

ITEM 7D

COST TO TAXPAYERS

COMPARATIVE COSTS TO TAXPAYERS – OVERVIEW

For comparative purposes, the following comparisons of various costs to taxpayers use the 2009 EAV, which is the last known EAV, for a direct comparison of the tax rates. This calculation method allows the reader to see the direct effect on the tax rate of adding additional O&M costs and/or capital costs to the District's current plan. In reality, over time, as the EAV increases, the tax rate decreases; however, the actual taxpayer costs increase. While most, if not all, of the comparative capital projects would take a number of years to design and construct, the following comparisons illustrate the full impact which would occur when all bonds are outstanding.

All of the comparisons are compared to the current 2011 budgeted tax levies, and the rates do not take into consideration the fact that the District's aggregate levy is budgeted at the maximum allowable under the tax cap for 2011. These comparisons are for illustration only; the District cannot legally increase the aggregate levy any further, which would be required to implement any of the following scenarios. Also, to award any of the additional capital projects used in the following comparisons, the District would need to delay or drop currently planned capital projects, since the current capital improvement program will consume the District's entire non-referendum bonding authority through 2024.

COMPARISON COSTS TO TAXPAYERS
UV Without Filtration

The District's overall budgeted tax rate for 2011 is estimated at 26.81 cents per $100 of EAV. For the purpose of comparison, UV disinfection without filtration costs of $22.1 million in O&M costs were added to the Corporate Fund levy and $36.4 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $491.1 million in bonds at 6% to be paid over 30 years using one annual payment for a level debt service. The 2009 EAV was used in both calculations because it is the latest available. The 2011 tax rate, including these UV disinfection costs without filtration equals 30.86 cents per $100 of EAV. This is an increase of approximately 4.05 cents per $100 of EAV or 15.1 percent from the budgeted 2011 tax rate. Table 2 details the comparison.

UV without Filtration			Table 2
LEVIES	2011 UV w/o Filtration	2011 ADOPTED	2010 AS ADJUSTED
Corporate Fund - O&M Costs $22,100,000	$ 270,600,000	$ 248,500,000	$ 240,207,200
Construction Fund	4,800,000	4,800,000	8,748,700
Stormwater Management Fund	24,100,000	24,100,000	24,028,900
Retirement Fund	28,162,600	28,162,600	26,478,000
Reserve Claim Fund	3,400,000	3,400,000	1,951,153
Subtotal	$ 331,062,600	$ 308,962,600	$ 301,413,953
Subtotal Bond Redemption & Interest Funds	$ 158,674,925	$ 158,674,925	$ 160,781,778
Capital Costs $491.1 M 30 Years 6%	36,338,986	-	
TOTAL	$ 526,076,511	$ 467,637,525	$ 462,195,731

TAX RATES COMPARISON
(In Cents)
Per $100 in Equalized Assessed Valuation

FUND	2011 Adopted UV w/o Filtration	2011 ADOPTED	2010 AS ADJUSTED
Gross Corporate Fund	15.51	14.24 ¢	13.77 ¢
Construction Fund	0.28	0.28	0.50
Stormwater Management Fund	1.38	1.38	1.38
Retirement Fund	1.61	1.61	1.52
Reserve Claim Fund	0.19	0.19	0.11
Subtotal	18.97	17.70 ¢	17.28 ¢
Subtotal Bond Redemption & Interest Funds	9.11 ¢	9.11 ¢	9.22 ¢
Capital Costs $491.1 M 30 Years 6%	2.78	-	-
TOTAL	30.86 ¢	26.81 ¢	26.50 ¢

2009 Equalized Assessed Valuation of $174,467,642,684 was used to estimate tax rates.

Change in Rate	15.1%

COMPARISON COSTS TO TAXPAYERS

UV With Filtration

The District's overall budgeted tax rate for 2011 is estimated at 26.81 cents per $100 of EAV. For the purpose of comparison, UV disinfection with filtration costs of $31.7 million in O&M costs were added to the Corporate Fund levy and $116.7 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $1,606.1 million in bonds at 6% to be paid over 30 years using one annual payment for a level debt service. The 2009 EAV was used in both calculations because it is the latest available. The 2011 tax rate, including these UV disinfection costs with filtration equals 37.57 cents per $100 of EAV. This is an increase of approximately 10.76 cents per $100 of EAV or 40.1 percent from the budgeted 2011 tax rate. Table 3 details the comparison. Cost estimates for UV with filtration are detailed in Table 8.

UV with Filtration			Table 3
	2011	**2011**	**2010**
LEVIES	**UV with Filtration**	**ADOPTED**	**AS ADJUSTED**
Corporate Fund - O&M Costs $31,700,000	$ 280,200,000	$ 248,500,000	$ 240,207,200
Construction Fund	4,800,000	4,800,000	8,748,700
Stormwater Management Fund	24,100,000	24,100,000	24,028,900
Retirement Fund	28,162,600	28,162,600	26,478,000
Reserve Claim Fund	3,400,000	3,400,000	1,951,153
Subtotal	$ 340,662,600	$ 308,962,600	$ 301,413,953
Subtotal Bond Redemption & Interest Funds	$ 158,674,925	$ 158,674,925	$ 160,781,778
Capital Costs $1,606.1 M 30 Years 6%	116,681,417	-	
TOTAL	$ 616,018,942	$ 467,637,525	$ 462,195,731

TAX RATES COMPARISON			
(In Cents)			
Per $100 in Equalized Assessed Valuation			
	2011 Adopted	**2011**	**2010**
FUND	**UV with Filtration**	**ADOPTED**	**AS ADJUSTED**
Gross Corporate Fund	16.06	14.24 ¢	13.77 ¢
Construction Fund	0.28	0.28	0.50
Stormwater Management Fund	1.38	1.38	1.38
Retirement Fund	1.61	1.61	1.52
Reserve Claim Fund	0.19	0.19	0.11
Subtotal	19.52	17.70 ¢	17.28 ¢
Subtotal Bond Redemption & Interest Funds	9.11 ¢	9.11 ¢	9.22 ¢
Capital Costs $1,606.1 M 30 Years 6%	8.94	-	-
TOTAL	37.57 ¢	26.81 ¢	26.50 ¢
2009 Equalized Assessed Valuation of $174,467,642,684 was used to estimate tax rates.			
Change in Rate	40.1%		

COMPARISON COSTS TO TAXPAYERS

UV, DO, and Lower Cost Nutrient Removal Option

The District's overall budgeted tax rate for 2011 is estimated at 26.81 cents per $100 of EAV. For the purpose of comparison, the UV, DO and lower cost nutrient removal option costs of $167.2 million in O&M costs were added to the Corporate Fund levy and $158.7 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $3,833.1 million in bonds at 6% to be paid over 30 years using one annual payment for a level debt service. The 2009 EAV was used in both calculations because it is the latest available. The 2011 tax rate, including these UV, DO and lower cost nutrient removal option costs equals 57.72 cents per $100 of EAV. This is an increase of approximately 30.91 cents per $100 of EAV or 115.3 percent from the budgeted 2011 tax rate. Table 4 details the comparison.

UV, DO, and Lower Cost Nutrient Removal Option			Table 4
LEVIES	2011 Nutrient UV DO	2011 ADOPTED	2010 AS ADJUSTED
Corporate Fund - O&M Costs $167,200,000	$ 415,700,000	$ 248,500,000	$ 240,207,200
Construction Fund	4,800,000	4,800,000	8,748,700
Stormwater Management Fund	24,100,000	24,100,000	24,028,900
Retirement Fund	28,162,600	28,162,600	26,478,000
Reserve Claim Fund	3,400,000	3,400,000	1,951,153
Subtotal	$ 476,162,600	$ 308,962,600	$ 301,413,953
Subtotal Bond Redemption & Interest Funds	$ 158,674,925	$ 158,674,925	$ 160,781,778
Capital Costs $3,833.1 M 30 Years 6%	278,470,543	-	
TOTAL	$ 913,308,068	$ 467,637,525	$ 462,195,731

TAX RATES COMPARISON

(In Cents)

Per $100 in Equalized Assessed Valuation

FUND	2011 Adopted Nutrient UV DO	2011 ADOPTED	2010 AS ADJUSTED
Gross Corporate Fund	23.83	14.24 ¢	13.77 ¢
Construction Fund	0.28	0.28	0.50
Stormwater Management Fund	1.38	1.38	1.38
Retirement Fund	1.61	1.61	1.52
Reserve Claim Fund	0.19	0.19	0.11
Subtotal	27.29	17.70 ¢	17.28 ¢
Subtotal Bond Redemption & Interest Funds	9.11 ¢	9.11 ¢	9.22 ¢
Capital Costs $3,833.1 M 30 Years 6%	21.32	-	-
TOTAL	57.72 ¢	26.81 ¢	26.50 ¢

2009 Equalized Assessed Valuation of $174,467,642,684 was used to estimate tax rates.

Change in Rate	115.3%

COMPARISON COSTS TO TAXPAYERS

UV, DO, and Higher Cost Nutrient Removal Option

The District's overall budgeted tax rate for 2011 is estimated at 26.81 cents per $100 of EAV. For the purpose of comparison, the UV, DO and higher cost nutrient removal option costs of $394.2 million in O&M costs were added to the Corporate Fund levy and $437.1 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $6,016.1 million in bonds at 6% to be paid over 30 years using one annual payment for a level debt service. The 2009 EAV was used in both calculations because it is the latest available. The 2011 tax rate, including these UV, DO and higher cost nutrient removal option costs equals 82.88 cents per $100 of EAV. This is an increase of approximately 56.07 cents per $100 of EAV or 209.1 percent from the budgeted 2011 tax rate. Table 5 details the comparison.

UV, DO, and Higher Cost Nutrient Removal Option — Table 5

LEVIES	2011 Nutrient UV DO	2011 ADOPTED	2010 AS ADJUSTED
Corporate Fund - O&M Costs $394,200,000	$ 642,700,000	$ 248,500,000	$ 240,207,200
Construction Fund	4,800,000	4,800,000	8,748,700
Stormwater Management Fund	24,100,000	24,100,000	24,028,900
Retirement Fund	28,162,600	28,162,600	26,478,000
Reserve Claim Fund	3,400,000	3,400,000	1,951,153
Subtotal	$ 703,162,600	$ 308,962,600	$ 301,413,953
Subtotal Bond Redemption & Interest Funds	$ 158,674,925	$ 158,674,925	$ 160,781,778
Capital Costs $6,016.1 M 30 Years 6%	437,063,117	-	
TOTAL	$ 1,298,900,642	$ 467,637,525	$ 462,195,731

TAX RATES COMPARISON

(In Cents)

Per $100 in Equalized Assessed Valuation

FUND	2011 Adopted Nutrient UV DO	2011 ADOPTED	2010 AS ADJUSTED
Gross Corporate Fund	36.84	14.24 ¢	13.77 ¢
Construction Fund	0.28	0.28	0.50
Stormwater Management Fund	1.38	1.38	1.38
Retirement Fund	1.61	1.61	1.52
Reserve Claim Fund	0.19	0.19	0.11
Subtotal	40.30	17.70 ¢	17.28 ¢
Subtotal Bond Redemption & Interest Funds	9.11 ¢	9.11 ¢	9.22 ¢
Capital Costs $6,016.1 M 30 Years 6%	33.47	-	-
TOTAL	82.88 ¢	26.81 ¢	26.50 ¢

2009 Equalized Assessed Valuation of $174,467,642,684 was used to estimate tax rates.

Change in Rate	209.1%

COMPARISON COSTS TO TAXPAYERS

Lower Cost Nutrient Removal Option Only

The District's overall budgeted tax rate for 2011 is estimated at 26.81 cents per $100 of EAV. For the purpose of comparison, the lower cost nutrient removal option only costs of $138.2 million in O&M costs were added to the Corporate Fund levy and $158.7 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $2,817.0 million in bonds at 6% to be paid over 30 years using one annual payment for a level debt service. The 2009 EAV was used in both calculations because it is the latest available. The 2011 tax rate, including these lower cost nutrient removal option only costs equals 50.40 cents per $100 of EAV. This is an increase of approximately 23.59 cents per $100 of EAV or 88.0 percent from the budgeted 2011 tax rate. Table 6 details the comparison.

Lower Cost Nutrient Removal Option Only			Table 6
	2011	**2011**	**2010**
LEVIES	**Nutrient UV DO**	**ADOPTED**	**AS ADJUSTED**
Corporate Fund - O&M Costs $138,200,000	$ 386,700,000	$ 248,500,000	$ 240,207,200
Construction Fund	4,800,000	4,800,000	8,748,700
Stormwater Management Fund	24,100,000	24,100,000	24,028,900
Retirement Fund	28,162,600	28,162,600	26,478,000
Reserve Claim Fund	3,400,000	3,400,000	1,951,153
Subtotal	$ 447,162,600	$ 308,962,600	$ 301,413,953
Subtotal Bond Redemption & Interest Funds	$ 158,674,925	$ 158,674,925	$ 160,781,778
Capital Costs $2,817.0 M 30 Years 6%	204,651,984	-	
TOTAL	$ 810,489,509	$ 467,637,525	$ 462,195,731
TAX RATES COMPARISON			
(In Cents)			
Per $100 in Equalized Assessed Valuation			
	2011 Adopted	**2011**	**2010**
FUND	**Nutrient UV DO**	**ADOPTED**	**AS ADJUSTED**
Gross Corporate Fund	22.16	14.24 ¢	13.77 ¢
Construction Fund	0.28	0.28	0.50
Stormwater Management Fund	1.38	1.38	1.38
Retirement Fund	1.61	1.61	1.52
Reserve Claim Fund	0.19	0.19	0.11
Subtotal	25.62	17.70 ¢	17.28 ¢
Subtotal Bond Redemption & Interest Funds	9.11 ¢	9.11 ¢	9.22 ¢
Capital Costs $2,817.0 M 30 Years 6%	15.67	-	-
TOTAL	50.40 ¢	26.81 ¢	26.50 ¢
2009 Equalized Assessed Valuation of $174,467,642,684 was used to estimate tax rates.			
Change in Rate	88.0%		

COMPARISON COSTS TO TAXPAYERS

Higher Cost Nutrient Removal Option Only

The District's overall budgeted tax rate for 2011 is estimated at 26.81 cents per $100 of EAV. For the purpose of comparison, the higher cost nutrient removal option only costs of $365.2 million in O&M costs were added to the Corporate Fund levy and $363.2 million of principal and interest costs were added for the capital costs. For simplicity, capital costs assumed the sale of $5,000.0 million in bonds at 6% to be paid over 30 years using one annual payment for a level debt service. The 2009 EAV was used in both calculations because it is the latest available. The 2011 tax rate, including these higher cost nutrient removal option only costs equals 75.57 cents per $100 of EAV. This is an increase of approximately 48.76 cents per $100 of EAV or 181.9 percent from the budgeted 2011 tax rate. Table 7 details the comparison.

Higher Cost Nutrient Removal Option Only			Table 7
	2011	**2011**	**2010**
LEVIES	**Nutrient UV DO**	**ADOPTED**	**AS ADJUSTED**
Corporate Fund - O&M Costs $365,200,000	$ 613,700,000	$ 248,500,000	$ 240,207,200
Construction Fund	4,800,000	4,800,000	8,748,700
Stormwater Management Fund	24,100,000	24,100,000	24,028,900
Retirement Fund	28,162,600	28,162,600	26,478,000
Reserve Claim Fund	3,400,000	3,400,000	1,951,153
Subtotal	$ 674,162,600	$ 308,962,600	$ 301,413,953
Subtotal Bond Redemption & Interest Funds	$ 158,674,925	$ 158,674,925	$ 160,781,778
Capital Costs $5,000.0 M 30 Years 6%	363,244,558	-	
TOTAL	$ 1,196,082,083	$ 467,637,525	$ 462,195,731
TAX RATES COMPARISON			
(In Cents)			
Per $100 in Equalized Assessed Valuation			
	2011 Adopted	**2011**	**2010**
FUND	**Nutrient UV DO**	**ADOPTED**	**AS ADJUSTED**
Gross Corporate Fund	35.18	14.24 ¢	13.77 ¢
Construction Fund	0.28	0.28	0.50
Stormwater Management Fund	1.38	1.38	1.38
Retirement Fund	1.61	1.61	1.52
Reserve Claim Fund	0.19	0.19	0.11
Subtotal	38.64	17.70 ¢	17.28 ¢
Subtotal Bond Redemption & Interest Funds	9.11 ¢	9.11 ¢	9.22 ¢
Capital Costs $5,000.0 M 30 Years 6%	27.82	-	-
TOTAL	75.57 ¢	26.81 ¢	26.50 ¢
2009 Equalized Assessed Valuation of $174,467,642,684 was used to estimate tax rates.			
Change in Rate	181.9%		

Metropolitan Water Reclamation District of Greater Chicago   Table 8

Engineering Department

Process Facilities Division

December 29, 2010

Opinion of Probable Costs of UV Disinfection and Tertiary Filtration at the North Side WRP, Stickney WRP, and Calumet WRP

	North Side WRP	Stickney WRP	Calumet WRP	Total for All Three WRPs
Capital Cost Estimates, in millions				
UV Disinfection [1]	$111.6	$267.2	$112.3	$491.1
Tertiary Filtration [2]	$184.0	$703.0	$228.0	$1,115.0
Total Capital Cost	$295.6	$970.2	$340.3	$1,606.1
Annual O&M Cost Estimates, in millions				
UV Disinfection [1]	$4.9	$12.6	$4.6	$22.1
Tertiary Filtration [2]	$2.5	$4.6	$2.5	$9.6
Total Annual O&M Cost	$7.4	$17.2	$7.1	$31.7

1. Source: Dr. David Zenz's written pre-filed testimony to the IPCB, submitted on October 27, 2008. Costs are in June 2008 dollars.

2. Source: Technical Memorandum-1WQ, dated August 26, 2005. The costs were subsequently adjusted to June 2008 dollars.

ITEM 7E

ITEM 7E

ECONOMIC ANALYSIS OF NUTRIENT REMOVAL

PURPOSE

The principal purpose of this economic assessment is to examine the financial capability of the Metropolitan Water Reclamation District of Greater Chicago (District) to operate and construct nutrient removal facilities, along with ultraviolet disinfection and dissolved oxygen facilities that would be necessary to meet the Illinois EPA's proposed effluent limits and water quality standards in the Chicago Area Waterway System (CAWS). This assessment incorporates recently enacted legislation that affects the District's current and future financial operations and financial capability. It also assesses the economic impacts of the relevant legislation and potential facility cost on the tax burden in dollars per Equalized Assessed Value (EAV).

Four financial alternatives are included in this report. The first is a baseline alternative that includes only currently planned capital projects. The second alternative includes currently planned capital projects and the costs associated with ultraviolet disinfection and dissolved oxygen facilities that would be necessary to meet the Illinois EPA proposed effluent limits and water quality standards in the CAWS. This alternative updates the alternative contained in the pre-filed testimony of John Mastracchio based on the recently enacted legislation as well as current economic conditions. Both the third and fourth alternatives include baseline and ultraviolet disinfection and dissolved oxygen costs along with two levels of nutrient removal.

COST SUMMARY

The assessment of the District's present and future financial capability under each of the alternatives was based on fiscal projection data from the Executive Director's 2011 Budget book, historical financial results reported in its Comprehensive Annual Financial Reports and cost estimates prepared by others. The economic assessment of implementing the nutrient removal facilities to the water reclamation system was prepared based on rudimentary, order-of-magnitude cost estimates developed for two potential effluent concentration limits for total nitrogen (TN) and total phosphorous (TP). The first cost estimate (herein referred to as the lower cost nutrient removal option) assumes hypothetical effluent limits of 0.5 mg/L for TP and between 6 to 8 mg/L for TN, and approximately $2.8 billion in capital costs and annual operations and maintenance (O&M) costs of $138.2 million (in 2008 dollars). The second cost estimate (herein referred to as the higher cost nutrient removal option) assumes hypothetical effluent limits of 0.1 mg/L for TP and 3 mg/L for TN, and approximately $5.0 billion in capital costs and annual O&M costs of $365.2 million (in 2007 dollars). The costs of constructing and operating ultraviolet disinfection facilities assume approximately $491.1 million in capital costs and $22.1 million in annual O&M costs (in 2008 dollars). The cost of constructing dissolved oxygen facilities assume $525 million in capital costs and $6.9 million in annual O&M costs (in 2008 dollars). The ultraviolet disinfection and dissolved oxygen estimates were based on the pre-filed testimony of Dr. David R. Zenz that was filed in 2008. The nutrient removal estimates were prepared by the District. The following table illustrates the assumed schedule estimate for implementation of the requisite facilities.

Implementation Timeframe Schedule for Ultraviolet Disinfection, Dissolved Oxygen and Nutrient Removal Facilities

	Pilot	Design	Construction
Ultraviolet Disinfection-Northside and Calumet Plants	2011-2013	2014-2016	2017-2019
Ultraviolet Disinfection-Stickney Plant	2011-2013	2014-2016	2017-2020
Dissolved Oxygen	2011-2012	2013-2016	2017-2019
Lower Cost Nutrient Removal Option	2013-2016	2017-2019	2020-2023
Higher Cost Nutrient Removal Option	2013-2016	2017-2019	2020-2023

ECONOMIC ASSESSMENT

The District generates revenue to fund its operations through an ad valorem property tax, a personal property replacement tax, user charges, interest income, and other miscellaneous fees and charges. The District's primary source of operating revenue is the ad valorem property tax. During the 2009 and 2010 legislative sessions, the Illinois General Assembly passed legislation affecting the District's capacity to generate revenue to take on additional projects or programs. In 2009, the General Assembly passed Public Act 96-0501 that amended the Illinois Property Tax Code and the Property Tax Extension Limitation Law to incorporate an annual increase in the District's debt service extension base of $141,463,920 equal to the lesser of the consumer price index or five percent. The General Assembly also enacted Public 96-0828 that exempts Build America Bonds (BABs) from the District's non-referendum bonding authority during the 2009 session. In 2009, the District issued $600 million in BABs. No BABs were issued by the District in 2010, and BABs are set to expire at the end of 2010. The passage of Public Act 93-279 in 2003 authorized the District to issue $150 million (previously $100 million) of non-referendum bonds during any budget year, plus authorized, but unissued bonds, during the previous three budget years through 2016. In 2010, the General Assembly passed Public Act 96-1308 that extends the sunset date for the District's non-referendum bonding authority from December 31, 2016 to December 31, 2024.

In addition to the recent legislative changes, several other financial limitations also affect the District's financial capability. The District's ability to adopt future increases in the aggregate tax levy was limited by the Property Tax Extension Limitation Law passed by the Illinois General Assembly in 1995. This Act limits increases to the District's aggregate levy to the lesser of: (1) five percent or (2) the change in the national consumer price index plus allowable increases for new property. Aggregate levy is the total levy of all funds except the Bond Redemption and Interest Fund and Stormwater Management Fund. The District's Tax Cap legislation restricts the District's non-referendum bonding authority for projects initiated before October 1, 1991.

A baseline financial capability assessment (Alternative 1) was prepared, which includes the District's currently planned capital projects, excluding the costs associated with ultraviolet disinfection, dissolved oxygen and nutrient removal projects. The updated estimated cost of the District's planned capital improvement projects were provided to Malcolm Pirnie in December 2010. The amount of these capital projects may be understated beyond 2017 because some future capital project needs are unknown at this time and are not reflected in the forecast. The baseline alternative indicates that the District has the financial capability to generate sufficient revenues to satisfy the District's projected revenue requirements within its Tax Cap Limitation through fiscal year 2024. However, under the baseline alternative, the District may not have sufficient funds in 2016 and 2017 to fund its existing capital program given its non-referendum bonding authority. Furthermore, the District's projected debt service is expected to narrowly exceed the debt service extension base beginning in 2016. A summary of the District's projected results under the baseline alternative compared to the financial limitations and restrictions is provided as Attachment 1 (Figures 1-1, 1-2 and 1-3).

Under the second alternative where ultraviolet disinfection and dissolved oxygen costs are included as part of the District's financial obligations, it is anticipated that the District will not have sufficient financial resources to fund the estimated capital expenditures and anticipated O&M costs. Under this alternative, the District cannot generate sufficient revenues within the constraints of the District's Tax Cap beginning in 2021. In addition, the District's debt financing needs would exceed its non-referendum bonding authority beginning in 2015, and its debt service would exceed its debt service extension limitation beginning in 2015. (See Attachment 2, Figures 2-1, 2-2 and 2-3)

Finally, if the District was to implement nutrient removal along with incurring costs associated with implementation of the ultraviolet disinfection and dissolved oxygen facilities, the District is expected to exceed its financial limitations even further. Under Alternative 3, which includes costs for ultraviolet disinfection, dissolved oxygen facilities, and the lower cost nutrient removal option, it is anticipated that the District would exceed its debt service extension limit beginning in 2015 and its tax cap limitation beginning in 2021. In addition, the District's debt financing needs would exceed its non-referendum bonding authority beginning in 2015 (See Attachment 3, Figures 3-1, 3-2 and 3-3)

Under Alternative 4, which includes costs for ultraviolet disinfection, dissolved oxygen facilities, and the higher nutrient removal option, it is anticipated that the District would exceed its debt service extension limitation beginning in 2015 and its tax cap limitation by 2021. In addition, the District's debt financing needs would greatly exceed its non-referendum bonding authority by 2015. (See Attachment 4, Figures 4-1, 4-2 and 4-3)

Even if the tax cap limitation, non-referendum bonding authority and debt service extension base were raised to allow the District to generate sufficient revenues to pay for the facilities, there would be a pronounced impact on the taxpayer if the District were to construct and operate ultraviolet disinfection and dissolved oxygen facilities and nutrient removal processes. Tax rates were estimated by forecasting the annual tax revenue requirements and equalized assessed value (EAV) over the forecast period, and then calculating the projected tax rates per $100 of EAV. Under the baseline alternative, it is estimated that tax rates would be

$0.27, $0.30, and $0.30 per $100 of EAV in 2011, 2021 and 2024, respectively. Under the second alternative (UV and DO), it is estimated that tax rates would be $0.27, $0.37, and $0.37 per $100 of EAV in 2011, 2021 and 2024 respectively. Under Alternative 3, the estimated tax rates would be $0.27, $0.43, and $0.54 per $100 of EAV, and under Alternative 4, the tax rates are estimated to be $0.27, $0.49, and $0.75 per $100 of EAV in 2011, 2021 and 2024.

It is important to note that the tax bill to a homeowner is impacted by the tax rate as well as the EAV. The forecast of tax rates shown above assume an increase in the EAV of 3.0 percent per year over the forecast period. As such, under each of the alternatives, the tax bill to a homeowner is projected to significantly increase, which is reflected in a combination of a higher tax rate and a higher EAV.

CONCLUSION

Given its financial limitations, the District does not have the financial capability to fully fund the projects and activities necessary to comply with IEPA's proposed rule. If the District was to implement nutrient removal along with incurring costs associated with ultraviolet disinfection and dissolved oxygen, the District's financial limitations would be exceeded even further. Furthermore, even if the tax cap limitation, non-referendum bonding authority and debt service extension base limitations were lifted to allow the District to finance and generate sufficient revenues to pay for the facilities, pronounced increases in the tax rate would be needed to pay for the facilities.

Attachment 1
Baseline Financial Results Compared to Financial Limitations and Restrictions (Alt 1)

Figure 1-1
Capital Program Expenditures and CIBF Ending Balance Forecast - Baseline

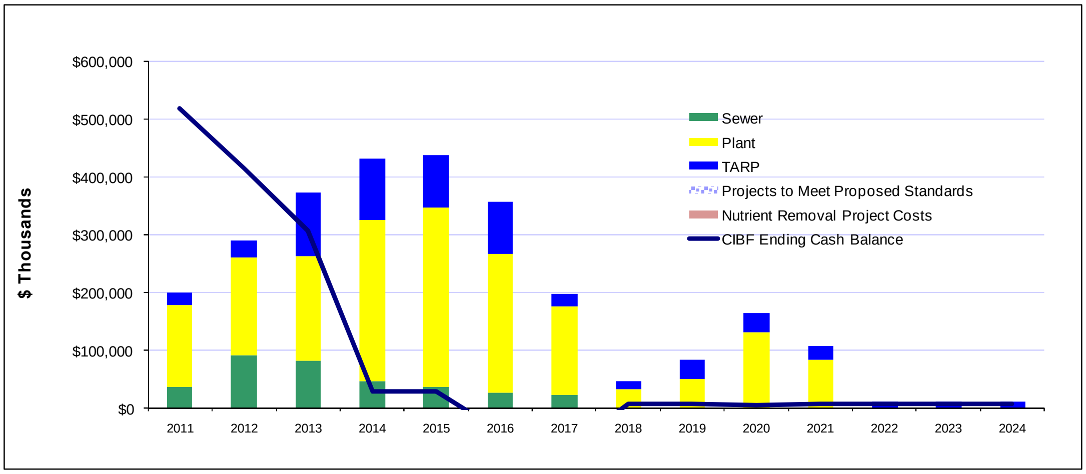


Figure 1-2
Forecasted Aggregate Tax Levy Requirement Compared to Tax Cap Limitation - Baseline

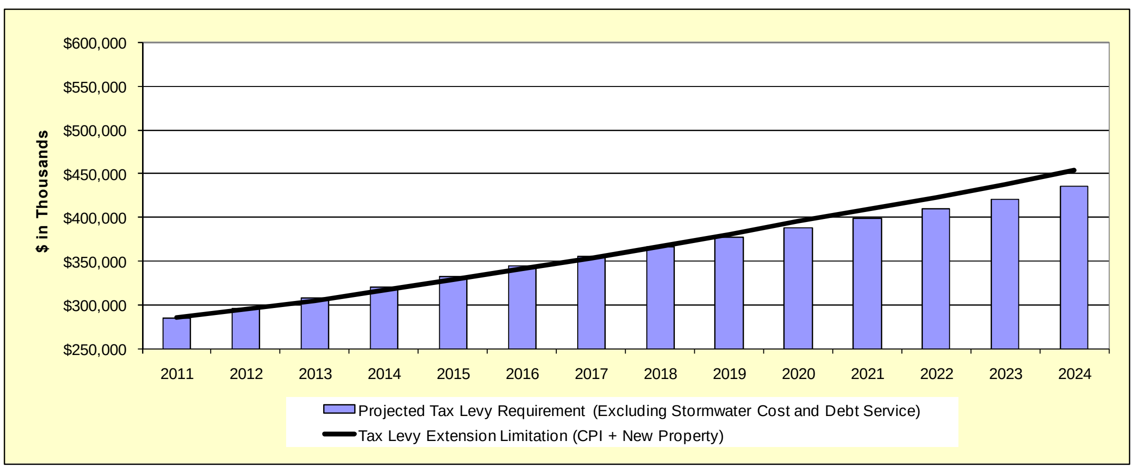
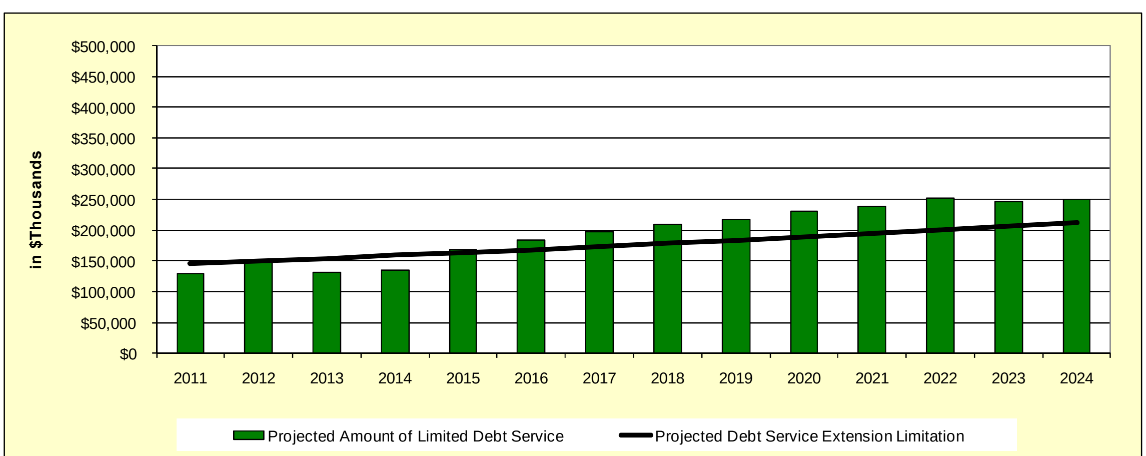


Figure 1-3
Forecasted Debt Service Compared to Debt Service Extension Base - Baseline



Attachment 2
Financial Results Including Dissolved Oxygen and Ultraviolet Disinfection Costs (Alt 2) Compared to Financial Limitations and Restrictions

Figure 2-1 –
Capital Program Expenditures and CIBF Ending Balance Forecast

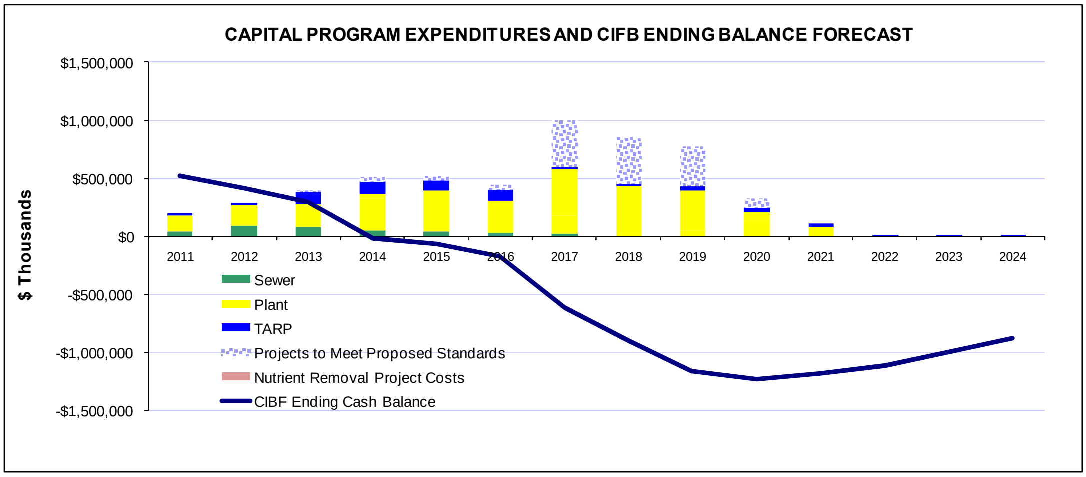


Figure 2-2
Forecasted Aggregate Levy Requirement Compared to Tax Cap Limitation

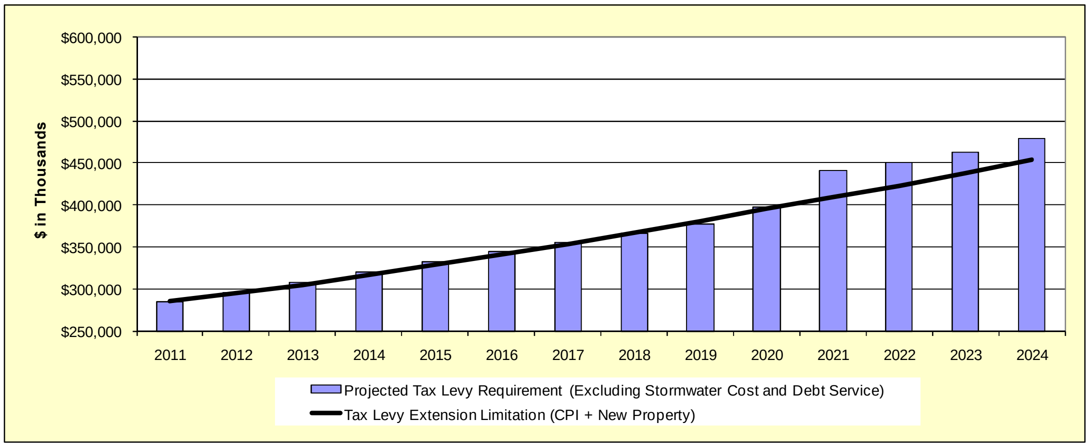
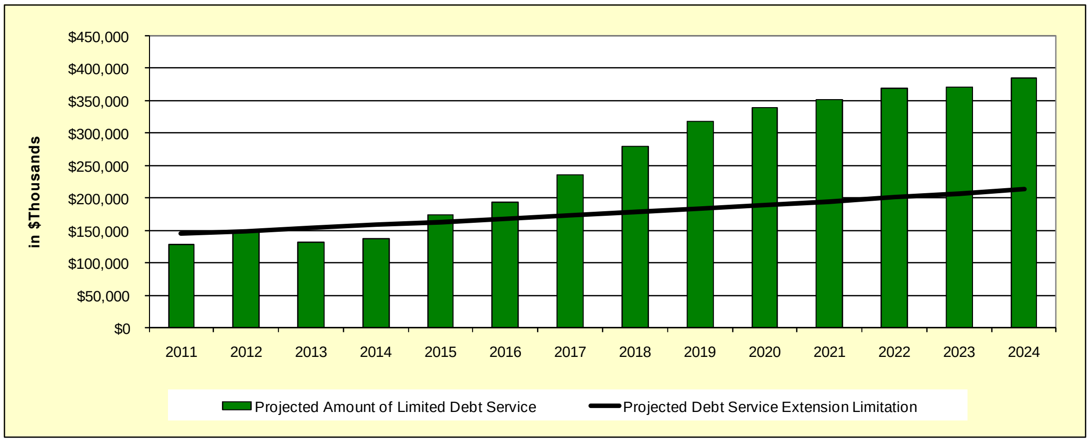


Figure 2-3
Forecasted Debt Service Compared to Debt Service Extension Base



Attachment 3

Financial Results Including Cost of Dissolved Oxygen, Ultraviolet Disinfection, and Lower Cost Nutrient Removal Option (Alt 3) Compared to Financial Limitations and Restrictions

Figure 3-1 - Capital Program Expenditures and CIBF Ending Balance Forecast

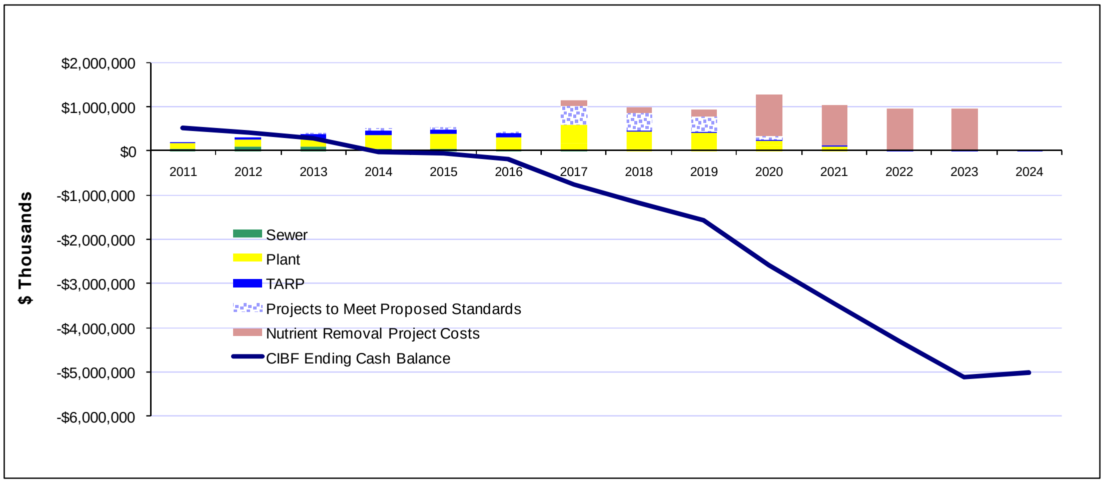


Figure 3-2
Forecasted Aggregate Levy Requirement Compared to Tax Cap Limitation

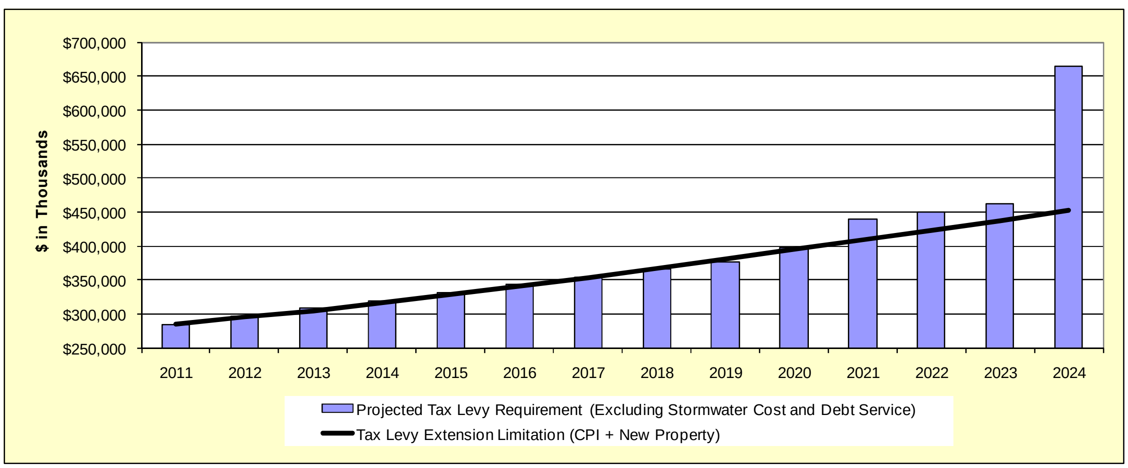
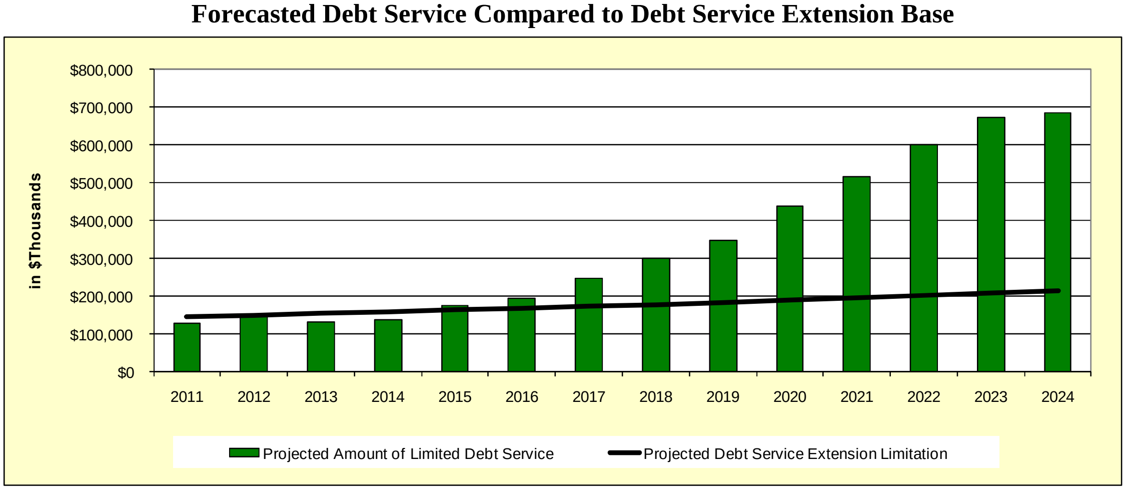


Figure 3-3
Forecasted Debt Service Compared to Debt Service Extension Base



Attachment 4

Financial Results Including Cost of Dissolved Oxygen, Ultraviolet Disinfection, and Higher Cost Nutrient Removal Option (Alt 4) Compared to Financial Limitations and Restrictions

Figure 4-1 - Capital Program Expenditures and CIBF Ending Balance Forecast

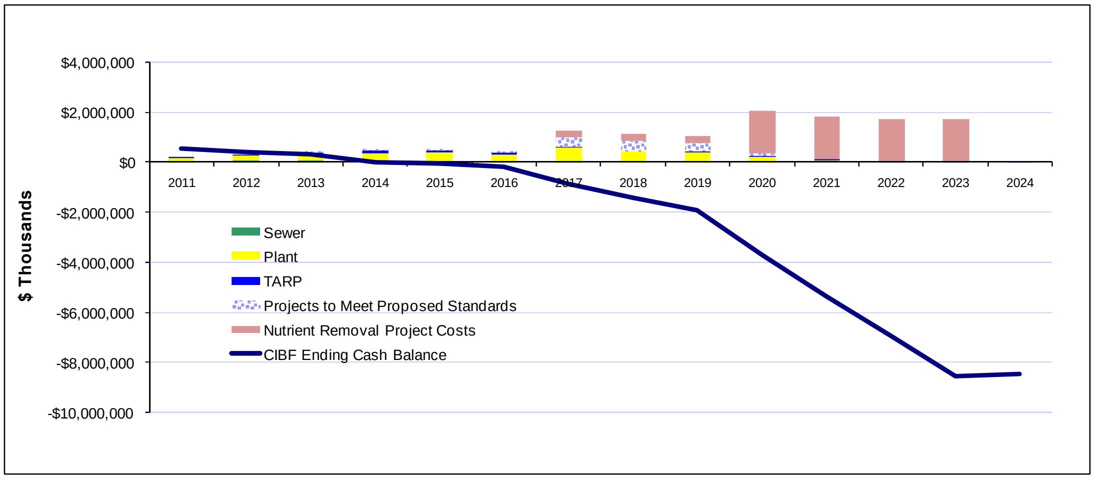


Figure 4-2
Forecasted Aggregate Levy Requirement Compared to Tax Cap Limitation

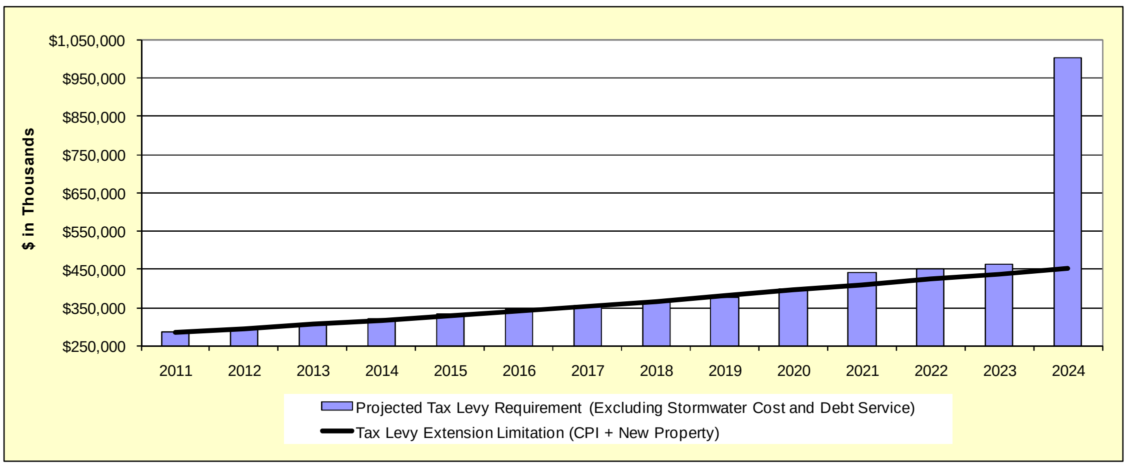
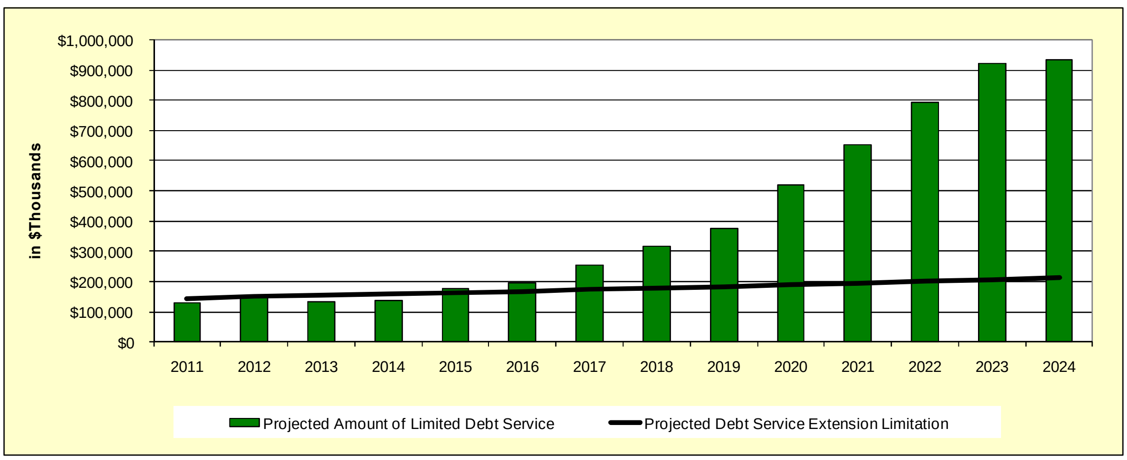


Figure 4-3
Forecasted Debt Service Compared to Debt Service Extension Base



ITEM 7F

ITEM 7F

EFFECT OF NUTRIENT REMOVAL ON EFFLUENT BACTERIA LEVELS

The expected regulatory requirements for nutrient removal would call for plant expansion at the District's Stickney, Calumet and North Side water reclamation plants (WRPs). The degree of expansion depends on the level of nutrient removal required. Even to meet Nutrient Removal Scenario 1, 0.5 mg/L for TP and 6 – 8 mg/L for TN, the plants need to add additional tankage for nitrogen and phosphorus removal and a tertiary treatment process, which is typically filtration, for removing nutrients in fine particulates.

According to the studies conducted by the District and other researchers, indicator microorganisms in the effluent will generally be lower as a result of plant expansion for nutrient removal. However, the removal rates of indicator microorganisms and their concentrations in the effluent will vary and are influenced by many design and operational factors. In the following sections, the results of various studies are summarized.

District Studies

In 2005 and 2006, concentrations of indicator bacteria were measured before and after filters at the District's John E. Egan and Hanover Park WRPs during non-disinfection seasons. The following table presents the average removal rates resulting from filtration and the bacterial concentrations in influents and effluents of the WRP's filters for two indicator bacteria along with the ranges represented by the perspective minimum and maximum values. The detailed results for this study are included as Attachment 1.

	Fecal Coliform (CFU/100mL)			E.coli (MPN/100 mL)		
	Before	After	Removal (%)	Before	After	Removal (%)
			Egan WRP			
Mean	3,864	2,092	43.7%	4,610	2,125	55.1%
Min	1,800	400	-35.0%	1,970	350	13.1%
Max	8,100	5,500	82.6%	9,210	6,870	83.7%
			Hanover Park WRP			
Mean	12,820	7,310	46.4%	11,284	6,925	31.7%
Min	2,500	200	19.1%	2,610	1,550	-5.8%
Max	60,000	38,000	95.6%	46,100	24,190	62.0%

In 2007 and 2008, District conducted a full-scale study on phosphorus (P) reduction at the John E. Egan WRP. In April 2008 when ferric chloride ($FeCl_3$) was applied to the secondary treatment system for P removal and no disinfection of effluent was required, the concentrations of fecal coliform (FC) in the secondary and filter effluents were measured. The average TP in the filter effluent was 0.22 mg/L during this period. The average removal rate of FC by filtration and FC concentrations in the secondary and filter effluents with the ranges in parentheses are shown in the following table. The individual measurement results are included as Attachment 2.

	Secondary Effluent (CFU/100mL)	Filter Effluent (CFU/100mL)	Removal (%)
Mean (range)	3791 (1261 to 7021)	**1603** (270 to 5860)	**59.6** (-27.7 to 87.9)

Other Studies Reported in Literature

Literature information on the removal of indicator microorganisms by biological and chemical nutrient removal processes is scarce. A Finnish study investigated *Salmonella* and FC removal by two pilot filters for the effluent from two conventional municipal wastewater treatment plants with chemical P removal (Koivunen et al., 2003). The average TP concentration in secondary treated wastewater before the filters was in the range of 0.3 to 0.5 mg/L. The average bacterial concentrations after the filter and removal rates by filters are shown as follows. The difference in removal efficiency between the two filters was attributed to the different types of filters.

	Secondary effluent	Filter effluent	Removal (%)
Salmonella (MPN/100mL) for both filters	< 3 to 240	< 3	> 99.3
FC (CFU/100mL)			
Rapid sand filter	49,000	**1,740**	**97**
Biological-chemical contact filter	40,700	**11,000**	**71**

In 2004, the Water Environment Research Foundation completed a comprehensive study for examining the reduction of pathogens, indicator bacteria and alternative indicators by wastewater treatment unit processes in six plants (Rose et al., 2004). One of the plants (F) has both N and P removal processes, another plant (E) uses a biological N removal process and the remaining plants (A, B, C and D) use the conventional activated sludge process. The influent flows to these plants ranged from 1 to 25 million gallons per day (MGD). All plants use a filtration process with rigid media except for Plant A that has fabric media. Plant B adds chlorine before the filters. The level of nutrient removal at the two plants (E and F) is unknown.

The average removal rates of indicator bacteria from the four plants that have the rigid media filtration processes, along with bacteria concentrations before and after the filtration units, are shown in the following table. The large variation in removal rates through filtration was attributed to media size, type and depth, hydraulic loading rates, operational variables (run time and backwash practices) and water quality variables (turbidity and pH), but not to indicator concentrations in the influent. Removal of pathogens by filtration was also observed in the WERF study. A summary is provided as Attachment 3.

Summary

The average removal rate of indicator bacteria, FC, in nutrient removal processes, particularly through filtration process, varied from approximately **60% to 98%,** depending on design parameters, such as media size, type and depth and hydraulic loading rates, and operational parameters. The average concentration of indicator bacteria in filtration effluents varied from plant to plant, ranging from **78 to 11,000 CFU/100 mL**. Daily concentrations of indicator bacteria were more variable, because the concentrations are influenced by many factors, which are systematically investigated by Hendricks et al (2005) for filtration removal of microorganisms in drinking water.

	Secondary effluent	Filter effluent	Removal (%)
FC (CFU/100mL)			
Conventional activated sludge + filter [1]	227,000 (C) and 16,500 (D)	731 (C) and 9,540 (D)	99.7 (C) and 42 (D)
Biological N removal process + filter [2]	30,100	20,200	33
N & P removal processes + filter [3]	4070	**78.1**	**98**
Enterococci (CFU/100mL)			
Conventional activated sludge + filter [1]	78,000 (C) and 2,940 (D)	17,900 (C) and 2,560 (D)	77 (C) and 13 (D)
Biological N removal process + filter [2]	7,490	580	92
N & P removal processes + filter [3]	899	84.1	91

Note: [1] The concentration data for Plant C and D is extracted from appendix tables of Rose et al (2004).
[2] The concentration data for Plant E is extracted from appendix tables of Rose et al (2004).
[3] The concentration data for Plant F is extracted from appendix tables of Rose et al (2004).

References.

Koivunen, J., Siitonen, A. and Heinonen-Tanski, H. "Elimination of enteric acteria in biological-chemical wastewater treatment and tertiary filtration units", *Water Research*, Vol 37, pp 690-698 (2003).

Rose, J.B., Nowlin, H., Farrah, S.R., Harwood, V.J., Levine, A.D., Lukasik, J., Menendez, P. and Scott, M.T. *Reduction of Pathogens, Indicator Bacteria, and Alternative Indicators by Wastewater Treatment and Reclamation Processes*, Report 00-PUM-2T, Water Environment Research Foundation (WERF), (2004).

Hendricks, D.W, Clunie, W.F., Sturbaum, G.D., Klein, D.A., Champlin, T.L., Kugrens, P., Hirsch, J., McCourt, B., Nordby, G.R., Sobsey, M.D., Hunt, D.J., and Allen, M.J. "Filtration Removal of Microorganisms and Particles", *Journal of Environmental Engineering*, Vol. 131, No. 12, pp. 1621-1632 (2005).

ITEM 7F

ATTACHMENT 1

Results of Indicator Bacteria Sampling for Conventional Secondary Effluent (Pre-Filter) and Tertiary Effluent (Post-Filter) at the Hanover Park Water Reclamation Plant

	Fecal Coliform (CFU/100mL)			Removal	E.coli (MPN/100mL)			Removal	Total Coliform (MPN/100mL)			Removal
Sample Date	Pre-Filter	Post-Filter	Reduction	(%)	Pre-Filter	Post-Filter	Reduction	(%)	Pre-Filter	Post-Filter	Reduction	(%)
11/16/05	22,000	9,500	12,500	56.8%	17,330	8,160	9,170	52.9%	155,300	92,100	63,200	40.7%
11/30/05	60,000	38,000	22,000	36.7%	46,100	24,190	21,910	47.5%	>241900	>241900	0	0.0%
12/14/05	14,000	9,400	4,600	32.9%	18,500	15,530	2,970	16.1%	241,900	173,300	68,600	28.4%
01/11/06	*	*	*	*	12,033	7,700	4,333	36.0%	130,000	77,010	52,990	40.8%
01/25/06	4,700	3,800	900	19.1%	6,870	2,610	4,260	62.0%	77,000	46,100	30,900	40.1%
02/08/06	4,200	2,500	1,700	40.5%	3,650	2,360	1,290	35.3%	20,500	15,500	5,000	24.4%
02/22/06	6,700	2,900	3,800	56.7%	6,130	4,610	1,520	24.8%	61,300	32,600	28,700	46.8%
03/08/06	2,500	1,700	800	32.0%	2,610	1,550	1,060	40.6%	24,200	15,500	8,700	36.0%
03/22/06	3,800	2,000	1,800	47.4%	3,260	3,450	-190	-5.8%	43,500	19,900	23,600	54.3%
04/05/06	4,500	200	4,300	95.6%	2,760	2,360	400	14.5%	32,600	19,900	12,700	39.0%
04/19/06	5,800	3,100	2,700	46.6%	4,880	3,650	1,230	25.2%	51,700	32,600	19,100	36.9%
AVE	**12,820**	**7,310**		**46.4%**	**11,284**	**6,925**		**31.7%**	**83,800**	**52,451**		**35.2%**
MIN	2,500	200		19.1%	2,610	1,550		-5.8%	20,500	15,500		0.0%
MAX	60,000	38,000		95.6%	46,100	24,190		62.0%	241,900	173,300		54.3%
GEOMEAN	**7,555**	**3,384**			**7,299**	**4,796**			**61,994**	**37,654**		

Note: *Pre-filter value of 1,200 and Post-filter of 4,900 gave large negative removal and were not included in summary.

ITEM 7F

Results of Indicator Bacteria Sampling for Conventional Secondary Effluent (Pre-Filter) and Tertiary Effluent (Post-Filter)
at the John E. Egan Water Reclamation Plant

	Fecal Coliform (CFU/100mL)			Removal	E.coli (MPN/100mL)			Removal	Total Coliform (MPN/100mL)			Removal
Sample Date	Pre-Filter	Post-Filter	Reduction	(%)	Pre-Filter	Post-Filter	Reduction	Pre-Filter	Post-Filter	Reduction	(%)	Pre-Filter
11/16/05	8,100	5,500	2,600	32.1%	9,210	6,870	2,340	25.4%	57,900	46,100	11,800	20.4%
11/30/05	5,000	2,600	2,400	48.0%	9,210	2,490	6,720	73.0%	112,000	37,800	74,200	66.3%
12/14/05	4,200	1,400	2,800	66.7%	5,480	1,010	4,470	81.6%	48,840	17,330	31,510	64.5%
01/11/06	4,100	2,000	2,100	51.2%	2,990	1,600	1,390	46.5%	24,190	14,140	10,050	41.5%
01/25/06	5,400	2,600	2,800	51.9%	3,970	3,450	520	13.1%	120,300	17,330	102,970	85.6%
02/08/06	2,800	1,500	1,300	46.4%	3,440	1,780	1,660	48.3%	34,500	14,100	20,400	59.1%
02/22/06	2,300	400	1,900	82.6%	2,143	350	1,793	83.7%	24,200	4,350	19,850	82.0%
03/08/06	3,400	2,000	1,400	41.2%	5,170	1,840	3,330	64.4%	43,500	20,100	23,400	53.8%
03/22/06	3,400	910	2,490	73.2%	3,260	1,070	2,190	67.2%	36,500	8,660	27,840	76.3%
04/05/06	2,000	2,700	-700	-35.0%	3,870	2,060	1,810	46.8%	46,100	24,200	21,900	47.5%
04/19/06	1,800	1,400	400	22.2%	1,970	860	1,110	56.3%	30,800	9,210	21,590	70.1%
AVG	**3,864**	**2,092**		**43.7%**	**4,610**	**2,125**		**55.1%**	**52,621**	**19,393**		**60.6%**
MIN	1,800	400		-35.0%	1,970	350		13.1%	24,190	4,350		20.4%
MAX	8,100	5,500		82.6%	9,210	6,870		83.7%	120,300	46,100		85.6%
GEOMEAN	**3,514**	**1,735**			**4,081**	**1,624**			**45,511**	**16,001**		

ITEM 7F

ATTACHMENT 2

Results of Secondary and Filtered Effluent Sampling during Phosphorus Reduction Study at the John E. Egan Water Reclamation Plant

Date	UVT (%)	TS (mg/L)	TSS (mg/L)	Total Fe (mg/L)	TP (mg/L)	Fecal coliform (CFU/100 mL)
Secondary Effluent						
4/1/2008	73.8	850	6	0.70	0.29	6751
4/2/2008	72.6	920	6	0.81	0.39	7021
4/3/2008	75.6	1016	6	0.53	0.13	4054
4/8/2008	74.7	962	6	0.67	0.32	1261
4/9/2008	73.1	822	6	0.79	0.43	2252
4/10/2008	73.7	922	7	0.51	0.37	1622
4/15/2008	73.5	898	44	3.48	1.26	2970
4/16/2008	74.0	862	8	1.03	0.41	3600
4/17/2008	77.0	902	0	0.1	0.27	4590
Min.	72.6	822	0	0.1	0.13	1261
Max.	77.0	1016	44	3.5	1.26	7021
Average	74.2	906	10	1.0	0.43	3791
Std. Dev.	1.4	59	13	1.0	0.32	2064
Final Effluent (after filtration)						
4/1/2008	68.5	946	8	1.57	0.47	818
4/2/2008	76.1	948	0	0.15	0.17	2252
4/3/2008	77.2	988	0	0.13	0.14	1081
4/8/2008	77.1	944	1	0.15	0.17	270
4/9/2008	72.9	900	2	0.49	0.27	545
4/10/2008	77.1	918	1	0.12	0.23	273
4/15/2008	76.9	888	0	0.13	0.13	1710
4/16/2008	79.5	874	0	0.12	0.14	1620
4/17/2008	76.5	902	0	0.12	0.28	5860
Min.	68.5	874	0.0	0.1	0.13	270
Max.	79.5	988	8.0	1.6	0.47	5860
Average	75.8	923	1.3	0.3	0.22	1603
Std. Dev.	3.2	36	2.6	0.5	0.11	1736

ITEM 7F

ATTACHMENT 3

Average Pathogen Concentrations before and after Filtration and Pathogen Removal Rates Reported in the WERF Study

	Secondary effluent	Filter effluent	Removal (%)
Coliphage –F-amp host (PFU/100mL)			
Conventional activated sludge + filter [1]	7,900 (C) and 745 (D)	3,870 (C) and 168 (D)	51 (C) and 77 (D)
Biological N removal process + filter [2]	819	141	83
N & P removal processes + filter [3]	71.7	25	65
Enterovirus (MPN/100L)			
Conventional activated sludge + filter [1]	166 (C) and 5.02 (D)	26.3 (C) and 2.67 (D)	84 (C) and 47 (D)
Biological N removal process + filter [2]	7.18	0.698	90
N & P removal processes + filter [3]	566	5.48	99
Giardia (cysts/100L)			
Conventional activated sludge + filter [1]	1,770 (C) and 1,450 (D)	19.9 (C) and 43.5 (D)	99 (C) and 97 (D)
Biological N removal process + filter [2]	92.8	36.4	61
N & P removal processes + filter [3]	559	17.9	97
Cryptosporidium (oocysts/100L)			
Conventional activated sludge + filter [1]	225 (C) and 72.6 (D)	206 (C) and 62.7 (D)	8 (C) and 14 (D)
Biological N removal process + filter [2]	37.2	13.7	63
N & P removal processes + filter [3]	58.8	7.15	88

Note: [1] The concentration data for Plant C and D is extracted from appendix tables of Rose et al (2004).
[2] The concentration data for Plant E is extracted from appendix tables of Rose et al (2004).
[3] The concentration data for Plant F is extracted from appendix tables of Rose et al (2004).

ITEM 8

ITEM 8

PROPOSED RECREATIONAL WATER QUALITY STANDARDS AND PERMIT REQUIREMENTS

The CHEERS Supplement, which was filed with the Board on December 6, 2010, concludes that there is no relationship between levels of bacterial parameters in the CAWS and risk of illness. Therefore, there is no technical basis to develop numeric water quality standards for those parameters based on protection of recreational uses. To ensure that those uses are protected, MWRD proposes instead that narrative criteria be adopted, which provide that levels of pathogen indicators shall not result in impairment of the designated uses, and that specific requirements be added that will help maintain compliance with those standards. For the MWRD treatment plants, these requirements would provide that the plants will comply with all provisions included in their NPDES permits, including suspended solids limits (which help reduce bacteria levels by removing solids that the bacteria are attached to) and operation and maintenance provisions (which ensure that MWRD continues to operate all of the advanced treatment systems that are currently specified in the permits).

As to wet-weather sources, including combined sewer overflow (CSO) discharges and discharges from municipal separate storm sewer systems (MS4s), a specific provision is necessary. During the times that these sources are present, and for a period of time afterward, the otherwise applicable uses and criteria may not be attained. During these time periods, the focus needs to be on making sure that the wet-weather sources are complying with existing requirements that minimize their contributions. For CSOs, that would mean compliance with the approved Long-Term Control Plan, which incorporates the eventual completion of TARP. For MS4s, that would mean compliance with requirements established by Illinois EPA in MS4 permits, including appropriate best management practices (BMPs) to reduce loadings contributed by those sources during wet-weather events. Based on data that have been collected by MWRD and discussed during the CAWS UAA hearings, the appropriate time period for application of the wet-weather provisions would be 72 hours after the conclusion of the wet-weather event.[1] Once a wet-weather event is over, and the effects of that event have passed, the regularly applicable uses and criteria would apply again.

Regulatory language that would implement this proposal is provided below.

--

SUBPART D: CHICAGO AREA WATERWAY SYSTEM AND LOWER DES PLAINES RIVER WATER QUALITY STANDARDS

Section 302.401 Scope and Applicability
Subpart D contains the Chicago Area Waterway System and Lower Des Plaines River water quality standards. These must be met only by waters specifically designated in Part 303. The Subpart B general use and Subpart C public water supply-standards of this Part do not apply to waters described in 35 Ill. Adm. Code 303.204 and listed in 35 Ill. Adm. Code 303.220 through 303.237 as the Chicano Area Waterway System or Lower Des Plaines River.

Section 302.402 Purpose
The Chicago Area Waterway System and Lower Des Plaines River standards shall protect incidental contact or non-contact recreational uses, except where designated as non-recreational waters; commercial activity, including navigation and industrial water supply uses; and the highest quality aquatic life and wildlife that is attainable, limited only by the physical condition of these waters and hydrologic modifications to these waters. The numeric and narrative standards contained in this Part will assure the protection of the aquatic life and recreational uses of the Chicago Area Waterway System and Lower Des Plaines River as those uses are defined in 35 Ill. Adm. Code Part 301 and

[1] This time period is based on data in this rulemaking record showing the extended impacts of wet-weather discharges on levels of pathogen indicators in the CAWS. See, for example, “CHEERS Research Update, An Interim Technical Report Prepared for Submission to the Pollution Control Board” (PC #300) at p. 18; see also Attachment 5 to Testimony of Geeta K. Rijal (MWRD Report No. 07-79) (filed Aug. 4, 2008).

designated in 35 Ill. Adm. Code Part 303.

Section 302.403 Pathogen Indicators
For Incidental Contact Recreation waters and Non-Contact Recreation waters, pathogen indicator levels shall not result in impairment of the applicable designated uses. To ensure compliance with this requirement, NPDES permittees discharging to or upstream of these waters shall comply with applicable requirements in their permits, including but not limited to Suspended Solids (SS) effluent limitations and operation and maintenance requirements. During and after wet-weather events, a wet-weather limited use designation shall apply instead of the otherwise applicable designated uses, and the following water quality-based requirements shall apply:

(1) Combined sewer overflow (CSO) discharges shall comply with the provisions of the approved CSO Long-Term Control Plan, as incorporated into the applicable NPDES permits; and
(2) Municipal separate storm sewer (MS4) discharges shall comply with best management practices (BMPs) and other requirements of the applicable NPDES permits.

The otherwise applicable designated uses and related narrative criteria shall apply again 72 hours after cessation of CSO and MS4 discharges that result from the wet-weather event.

ITEM 9

ITEM 9

ECONOMIC ANALYSIS FOR MWRD'S PROPOSED STANDARDS AND LIMITS

As explained in Exhibit 8, the CHEERS Supplement, which was filed with the Board on December 6, 2010, concludes that there is no relationship between levels of bacterial parameters in the CAWS and risk of illness. Therefore, there is no technical basis to develop numeric water quality standards for those parameters based on protection of recreational uses. To ensure that those uses continue to be protected, MWRD proposes instead (in Exhibit 8) that narrative criteria be adopted, which provide that levels of pathogen indicators shall not result in impairment of the designated uses, and that specific requirements be added that will help maintain compliance with those standards. For the MWRD treatment plants, these requirements would specify that the plants will comply with all provisions included in their NPDES permits, and that MWRD continue to operate all of the advanced treatment systems that are specified in those permits. Also, the MWRD proposal would specify that during and after wet-weather events, combined sewer overflow (CSO) and municipal separate storm sewer (MS4) discharges must comply with applicable requirements in their permits, including implementation of TARP as provided in the CSO Long-Term Control Plan.

Because the MWRD proposal in Exhibit 8 would not require installation of disinfection systems at the MWRD's treatment plants, it would not result in incremental costs for control of pathogen indicators. However, MWRD would still have to incur substantial capital and operation/maintenance costs over time to maintain compliance with existing requirements that are referenced in the proposal, including implementation of TARP for CSOs. Also, MWRD would still incur substantial costs to meet IEPA's proposed dissolved oxygen (DO) standards if those are adopted by the Board, and would also have to incur the control costs that would result if and when Federal and/or State requirements are imposed to reduce nutrient discharges from the treatment plants. Those costs, and their economic impacts, are discussed in detail in Exhibits 7B, 7D and 7E. As discussed in Exhibit 7F, installation of nutrient controls would be expected to result in substantial reductions in effluent bacteria levels, without the need to incur additional costs for disinfection systems.

ITEM 10

ITEM 10

INFORMATION ON INDICATOR LEVELS PROTECTIVE OF RECREATIONAL USES

As discussed in Exhibit 8, the CHEERS Supplement, which was filed with the Board on December 6, 2010, concludes that there is no relationship between levels of bacterial parameters in the CAWS and risk of illness. Therefore, there is no technical basis to develop numeric water quality standards for those parameters based on protection of recreational uses. To ensure that those uses continue to be protected, MWRD proposes instead (in Exhibit 8) that narrative criteria be adopted, which provide that levels of pathogen indicators shall not result in impairment of the designated uses, and that specific requirements be added that will help maintain compliance with those standards. For the MWRD treatment plants, these requirements would specify that the plants will comply with all provisions included in their NPDES permits, and that MWRD continue to operate all of the advanced treatment systems that are specified in those permits. Also, the MWRD proposal would specify that during and after wet-weather events, combined sewer overflow (CSO) and municipal separate storm sewer (MS4) discharges must comply with applicable requirements in their permits, including implementation of TARP as provided in the CSO Long-Term Control Plan. These provisions would ensure continued protection of applicable recreational uses for all reaches of the CAWS.

ITEM 11

ITEM 11

UPDATE ON STATUS OF TUNNEL AND RESERVOIR PLAN (TARP)

Attached is the District's TARP Status Report as of December 1, 2010. The TARP system will be completed when the Thornton Composite Reservoir and the McCook Reservoir Stages 1 and 2 are operational. The Thornton Composite Reservoir is estimated to be completed in 2015, and Stages 1 and 2 of the McCook Reservoir are estimated to be completed in 2017 and 2029, respectively.

Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago
100 East Erie Street Chicago, Illinois 60611-3154 fax: 312.7515659 312.751.5650

TARP STATUS REPORT AS OF DECEMBER 1, 2010

This report presents construction progress, cost, and State/Federal grant and revolving loan funding information on the Tunnel and Reservoir Plan (TARP). Figures 1 through 4 herein are maps of TARP facilities, and Tables I through IV contain data on TARP contracts. Project reference numbers appearing in Tables II and III correspond to the numbers shown on Figures 2, 3, and 4.

TARP Phase I

TARP, or "Deep Tunnel," was selected in 1972 as the Chicago area's plan for cost-effectively complying with Federal and State water quality standards with respect to the 375 square mile combined sewer area consisting of Chicago and 51 suburbs. TARP's main goals are to protect Lake Michigan – the region's drinking water supply - from raw sewage pollution; improve the water quality of area rivers and streams; and provide an outlet for floodwaters to reduce street and basement sewage backup flooding. TARP Phase I projects are primarily for pollution control. These projects - reference nos. 1 through 29 - capture and enable treatment of about 85% of the combined sewer overflow (CSO) pollution from TARP's service area. TARP Phase I includes 109.4 miles of deep, large diameter, rock tunnels. Construction of TARP Phase I was completed in 2006 and the entire system is now in operation. The table below summarizes the tunnel system.

TARP SYSTEM	TUNNEL LENGTH	TUNNEL VOLUME	TUNNEL DIAMETER
Mainstream	40.5 mi.	1,200 MG	8 to 33 ft.
Calumet	36.7 mi.	630 MG	9 to 30 ft.
O'Hare (UDP)	6.6 mi.	70 MG	9 to 20 ft.
Des Plaines	25.6 mi.	405 MG	10 to 33 ft.
TOTALS	109.4 mi.	2,305 MG	8 to 33 ft.

TARP Phase II/CUP

TARP Phase II/CUP consists of reservoirs intended primarily for flood control for the Chicagoland combined sewer area, but it will also considerably enhance pollution control benefits being provided under Phase I. The U.S. Army Corps of Engineers' Chicagoland Underflow Plan (CUP), Final Phase I General Design Memorandum (GDM) of 1986 defined the Federal interest in TARP Phase II based on the Federal National Economic Development Plan criteria. The three reservoirs proposed under TARP Phase II/CUP are the Gloria Alitto Majewski Reservoir (previously the O'Hare CUP Reservoir), the Thornton Reservoir, and the McCook Reservoir.

Gloria Alitto Majewski Reservoir

As the local sponsor of TARP Phase II/CUP, the MWRDGC acquired land rights for the reservoir. The U.S. Army Corps of Engineers (USACE) designed and constructed the reservoir, which was completed in 1998. The District has since assumed its operation, and to date the reservoir has yielded $207 million in flood damage reduction benefits to the three communities it serves.

Thornton Reservoir

The Thornton Reservoir will be constructed in two stages. The first stage, a temporary 3.1 billion gallon Natural Resources Conservation Service (NRCS) reservoir called the Thornton Transitional Reservoir, was completed in March 2003 in the West Lobe of the Thornton Quarry. This reservoir provides overbank flood relief for 9 communities, and has captured 23.3 billion gallons of flood water during 35 fill events.

The second stage is a permanent 7.9 billion gallon combined NRCS/CUP reservoir, called the Thornton Composite Reservoir, being constructed in the North Lobe of the Thornton Quarry. The Thornton Composite Reservoir will provide 3.1 billion gallons of storage for the NRCS overbank flooding area and 4.8 billion gallons of storage for the TARP Phase II/CUP combined sewer area. Mining of the North Lobe for the Thornton Composite Reservoir commenced in 1998 and is on schedule to be completed in 2013. The composite reservoir will then be completed in 2015, after which the transitional reservoir in the West Lobe will be decommissioned and returned to an active quarry. The Thornton Composite Reservoir will provide $40 million per year in benefits to 556,000 people in 14 communities.

The USACE was authorized to conduct a Limited Re-evaluation Report (LRR) to justify taking financial responsibility of the NRCS portion of the Thornton Composite Reservoir under the Water Resources Development Act of 1999. The LRR was completed in July 2003. On September 18, 2003 the USACE and MWRDGC signed a Project Cooperation Agreement (PCA) for construction of the Thornton Composite Reservoir. The USACE credited the MWRDGC $57,000,000 for money the MWRDGC spent on the relocation of Vincennes Avenue, land acquisition, and transitional reservoir facilities that will also be used by the composite reservoir. However, due to inadequate funding levels by the USACE and the need to have the Composite Reservoir online before the transitional reservoir is returned to the quarry, the MWRDGC, in June 2004, assumed responsibility for the design and construction of the reservoir, and will pursue reimbursement of funds through the Water Resources Development Act. As a result, three contracts totaling about $294,000,000 were designed and bid and are now under construction to complete the major work required to make the Composite Reservoir operational. Another contract to provide surface aeration is planned to begin design in 2012.

McCook Reservoir

The MWRDGC owns the land for the McCook Reservoir, which will be built within the Lawndale Avenue Solids Management Area (LASMA). A PCA with the USACE was signed on May 10, 1999. The USACE is responsible for designing and constructing the reservoir features, and the MWRDGC is responsible for providing the massive hole for the reservoir. The reservoir is planned to be completed in two stages. The first stage will provide 3.5 billion gallons of storage and is expected to be completed in 2017. The second stage has been expanded to 6.5 billion gallons and replaces the previously planned third stage. The McCook Reservoir will provide $90 million per year in benefits to 3.1 million people in 37 communities.

USACE has begun design and construction work on the McCook Reservoir. Seven construction contracts awarded by the USACE have been completed, including construction of a groundwater cutoff wall around the reservoir, a grout curtain contract around half the reservoir, rock wall stabilization work inside the reservoir, distribution tunnels between the reservoir and the pumping station, and a pumps and motors contract. Construction of the Stage 2 Grout Curtain, the Main Tunnels Shaft Excavation, the Main Gates, and the Stage 1 Retaining Wall are in progress.

In October 2003, the MWRDGC signed an agreement with a local mining company to mine out the limestone to the limits of the McCook Reservoir. The MWRDGC completed contracts to construct a rock tunnel connecting the existing quarry to the reservoir site and to construct mining facilities that are required to crush and convey the crushed rock to the quarry for processing. Full production mining at the site began in March 2008 and will continue for approximately nineteen years. The MWRDGC has completed removal of approximately 7.5 million cubic yards of overburden lying above the rock, at the reservoir site.

Reservoir storage volumes are presented in the table below.

PHASE II/CUP RESERVOIR	VOLUME (in billion gallons)
Majewski	0.35
Thornton	4.8 *
McCook	10.0
TOTAL STORAGE	15.15

* Does not include 3.1 billion gallon portion designated for non-TARP overbank flood relief.

TARP/CUP Costs

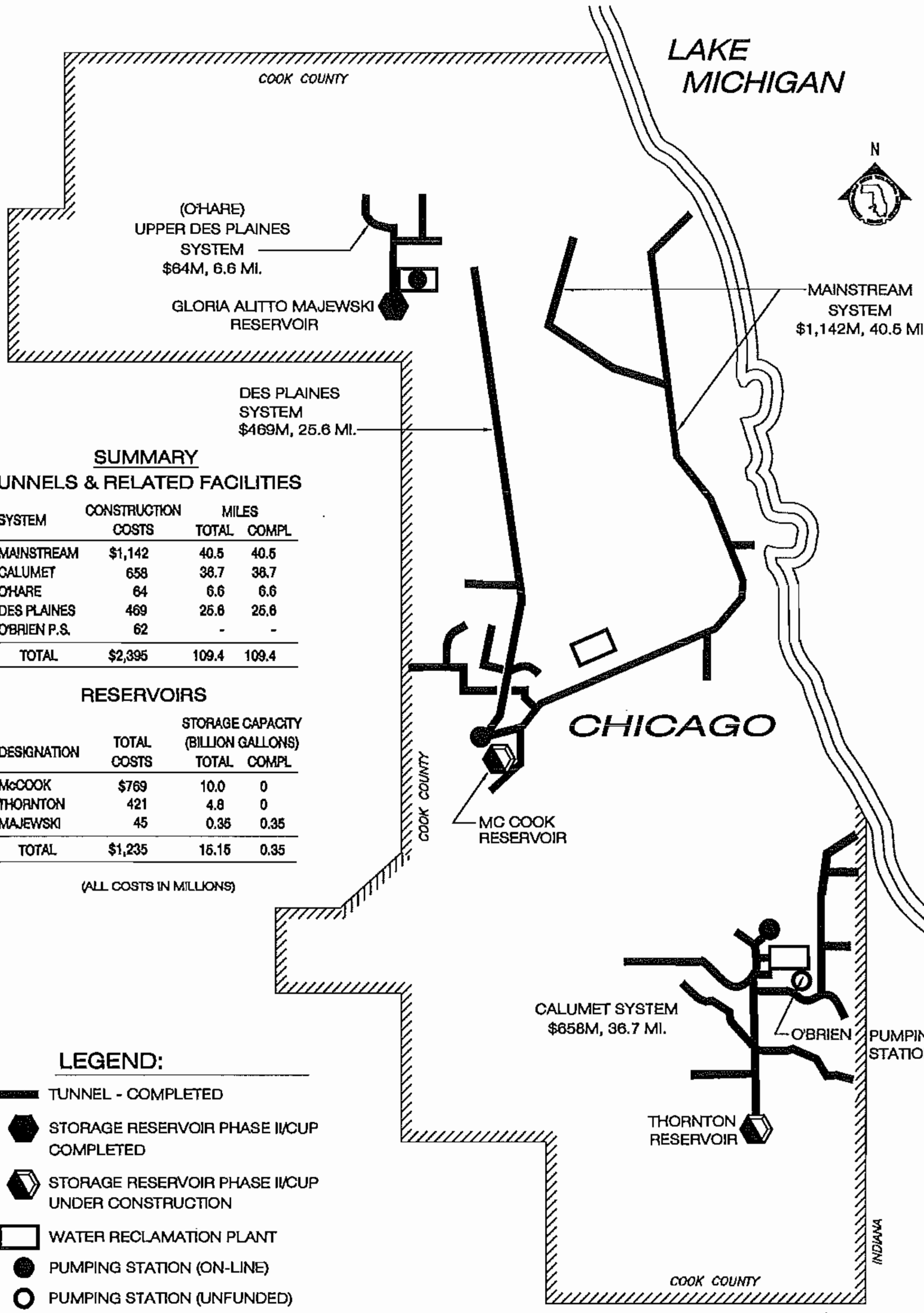
Current TARP/CUP costs, details of which are provided in Tables I through IV, are summarized as follows:

(A) Phase I Tunnels & Appurtenant Facilities (Construction Costs)	
(1) Completed	$2,332,154,822
(2) Remaining	$ 62,352,000
Total Tunnels & Appurtenant Facilities	$2,394,506,822
(B) Phase II/CUP Reservoirs (Total Project Costs)	
(1) Majewski Reservoir:	
Completed	$ 44,810,552
Remaining	$ 0
Sub-Total Majewski Reservoir	$ 44,810,552
(2) Thornton Reservoir:	
Completed/Under Construction	$ 384,150,000
Remaining	$ 36,769,000
Sub-Total Thornton Reservoir	$ 420,919,000
(3) McCook Reservoir:	
Completed/Under Construction	$ 512,957,000
Remaining	$ 255,970,000
Sub-Total McCook Reservoir	$ 768,927,000
Total Reservoirs	$1,234,656,552
Total Tunnel and Reservoir Plan	$3,629,163,374

Very truly yours,

Kenneth Kits
Director of Engineering

WSS:KMF
w/attachments



SUMMARY

TUNNELS & RELATED FACILITIES

SYSTEM	CONSTRUCTION COSTS	MILES TOTAL	MILES COMPL
MAINSTREAM	$1,142	40.5	40.5
CALUMET	658	36.7	36.7
O'HARE	64	6.6	6.6
DES PLAINES	469	25.6	25.6
O'BRIEN P.S.	62	-	-
TOTAL	$2,395	109.4	109.4

RESERVOIRS

DESIGNATION	TOTAL COSTS	STORAGE CAPACITY (BILLION GALLONS) TOTAL	COMPL
McCOOK	$769	10.0	0
THORNTON	421	4.8	0
MAJEWSKI	45	0.35	0.35
TOTAL	$1,235	15.15	0.35

(ALL COSTS IN MILLIONS)

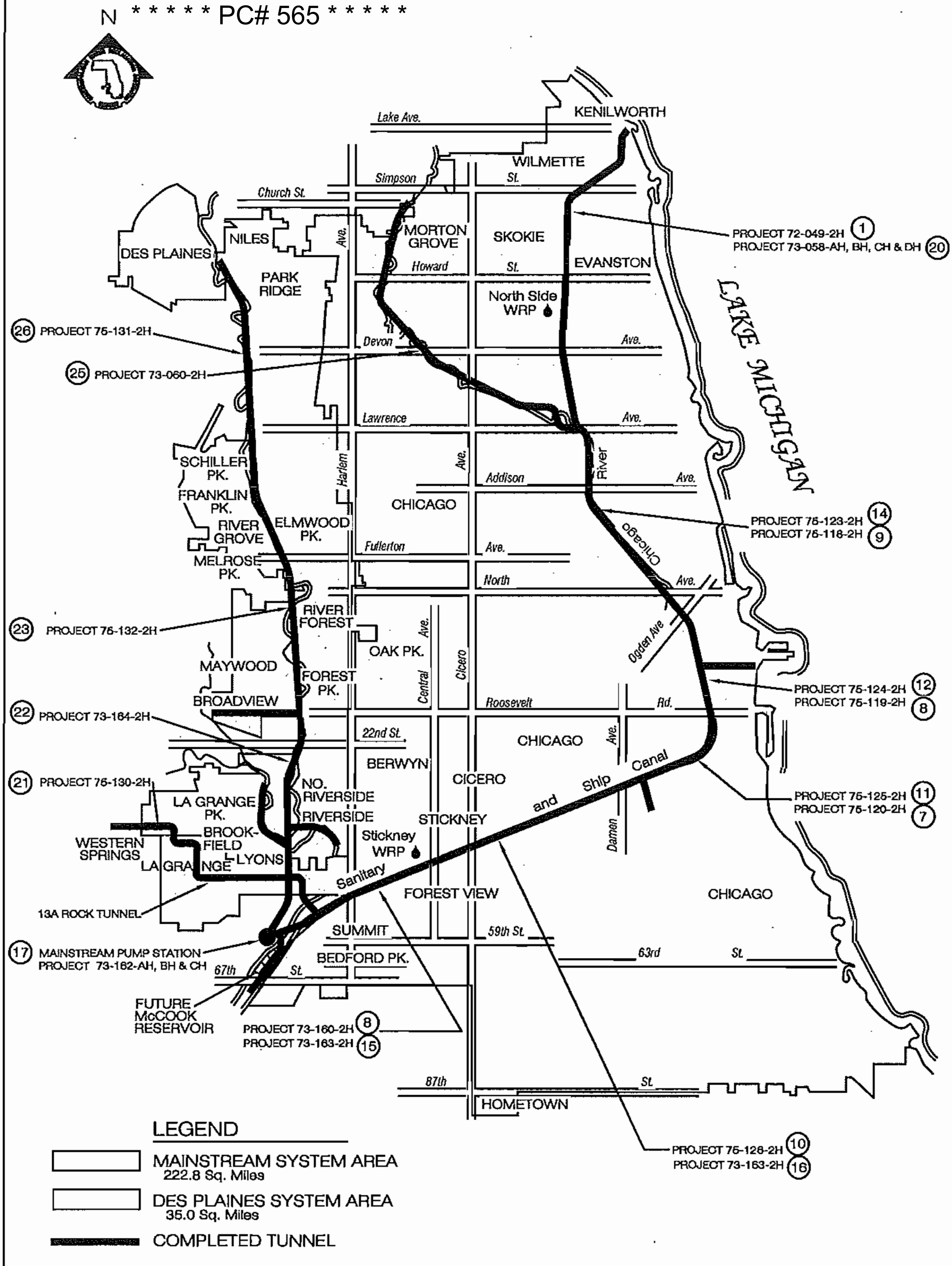
LEGEND:

- TUNNEL - COMPLETED
- STORAGE RESERVOIR PHASE II/CUP COMPLETED
- STORAGE RESERVOIR PHASE II/CUP UNDER CONSTRUCTION
- WATER RECLAMATION PLANT
- PUMPING STATION (ON-LINE)
- PUMPING STATION (UNFUNDED)

TUNNEL and RESERVOIR PLAN PROJECT STATUS

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
ENGINEERING DEPARTMENT
TARP & PROJECT SUPPORT KMF:JJK

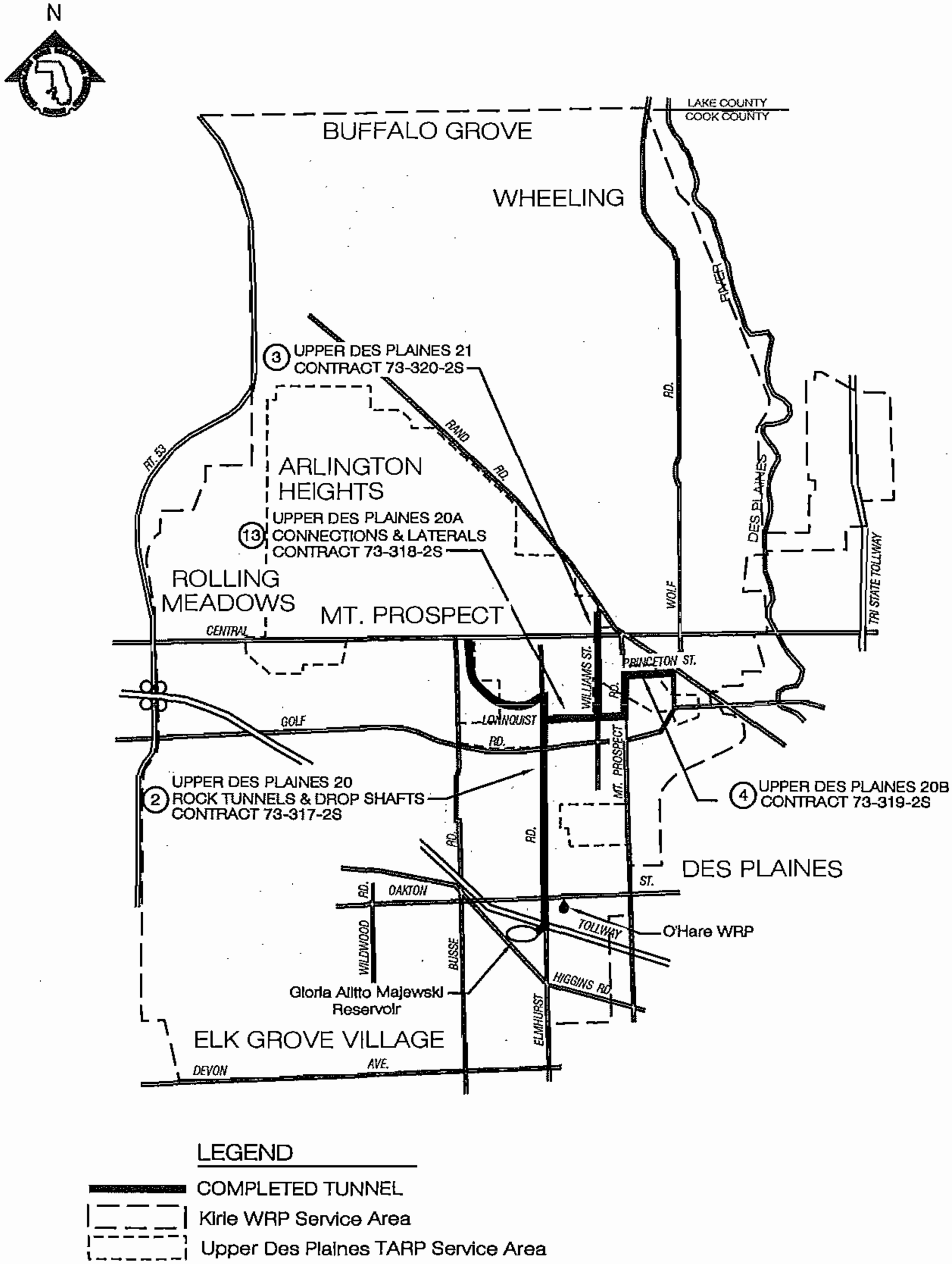
Figure 1



TARP - MAINSTREAM and DES PLAINES SYSTEMS

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
ENGINEERING DEPARTMENT
TARP & PROJECT SUPPORT KMF:JJK

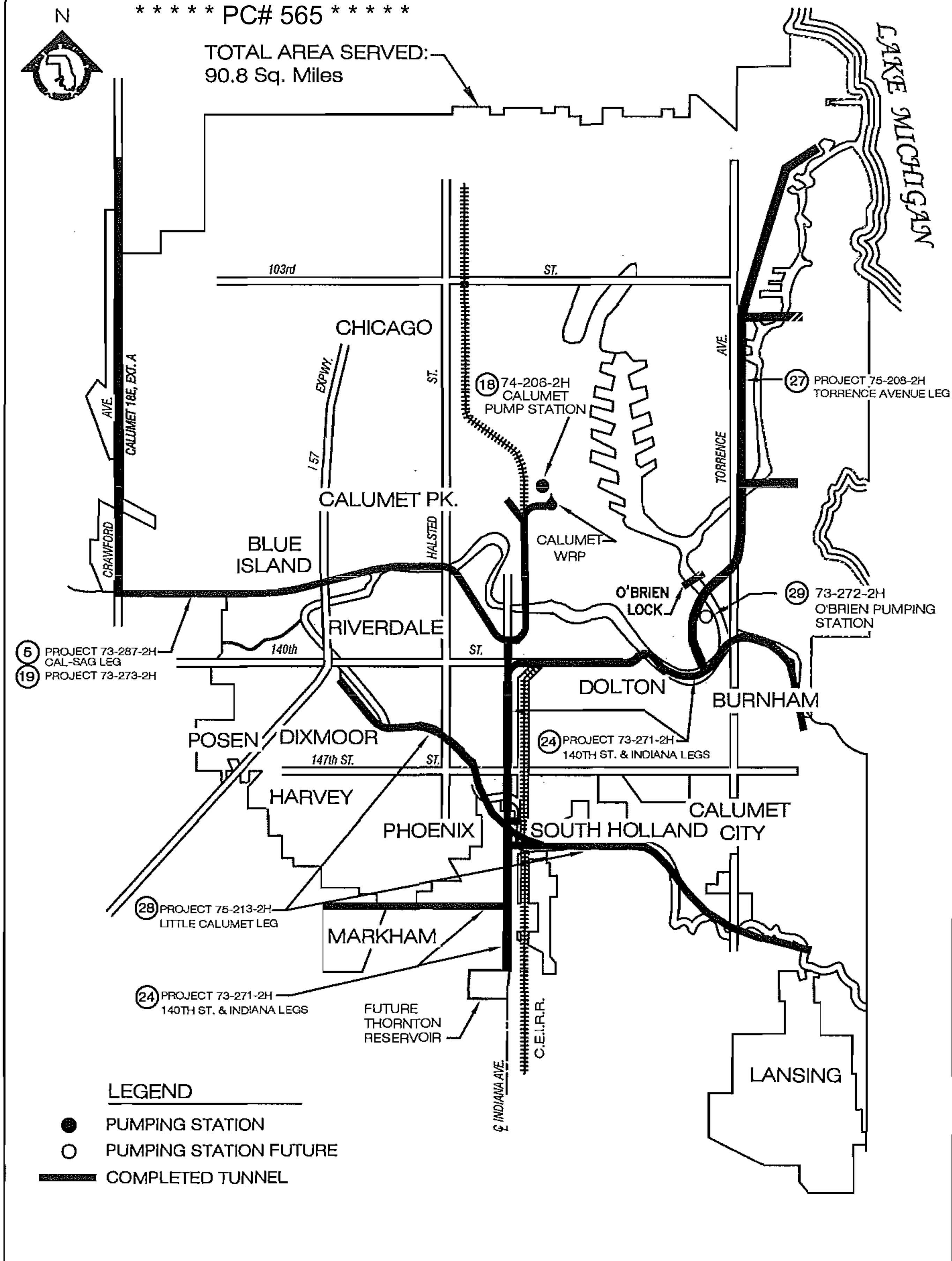
Figure 2



TARP - UPPER DES PLAINES (O'HARE) SYSTEM

METROPOLITAN WATER RECLAMATION
DISTRICT OF GREATER CHICAGO
ENGINEERING DEPARTMENT
TARP & PROJECT SUPPORT KMF:JJK

Figure 3



TARP - CALUMET SYSTEM

METROPOLITAN WATER RECLAMATION
DISTRICT OF GREATER CHICAGO
ENGINEERING DEPARTMENT
TARP & PROJECT SUPPORT KMF:JJK

Figure 4

TABLE I
TARP Phase I Funding Status
as of 12/01/2010 (Costs in Millions)

	1	2	3	4	5	6
TARP System	*Total Construction Cost(a)*	*Construction Completed*	*Construction In Progress*	*Being Advertised*	*Amount Funded(b)*	*Currently Unfunded*
Mainstream	*$1,142*	*$1,142*	*$0*	*$0*	*$1,142*	*$0*
Calumet	*$720*	*$658*	*$0*	*$0*	*$658*	*$62*
O'Hare	*$64*	*$64*	*$0*	*$0*	*$64*	*$0*
Des Plaines	*$469*	*$469*	*$0*	*$0*	*$469*	*$0*
Total	*$2,395*	*$2,333*	*$0*	*$0*	*$2,333*	*$62*

(a) Costs in Column 1 consist of contract award costs and current estimated costs for applicable remaining construction.

(b) Additional TARP-related contracts funded but excluded from Column 5 are:

1. Mainstream System Bulkhead Removal Contract (82-178-2H)	*$2,937,462*	*(Completed)*
2. Mainstream System Groundwater Monitoring Wells-Contract (73-162-DH)	*$674,600*	*(Completed)*
3. Calumet System Bulkhead Removal Contract (82-243-2H)	*$335,728*	*(Completed)*
4. Calumet System Groundwater Monitoring Wells (Contract 74-206-BH)	*$128,900*	*(Completed)*
5. Mainstream Pitney Ct. Sewer (Contract 75-120-KH)	*$278,856*	*(Completed)*
6. Mainstream Drop Shafts-Installation of Louvers (Contract 85-122-2H)	*$496,600*	*(Completed)*
7. Mainstream Slide Gate Installation (Contract 86-131-2H)	*$673,000*	*(Completed)*
8. S.W. 13-A Groundwater Monitoring Wells (Contract 73-172-2H)	*$27,750*	*(Completed)*
9. Mainstream Oxygen Injection System (Contract 85-113-AM)	*$247,700*	*(Completed)*
Total	*$5,800,596*	

TABLE II

TARP Phase I Contracts Completed

Ref. No. (1)	*Project Name*	*Project Number*	*Contractor*	*Project Cost (2)*
	Mainstream System			
1	*Addison-Wilmette Tunnel*	72-049-2H	*Kenny-Paschen, S & M J.V.*	$63,140,480
6	*59th to Central Tunnel*	73-160-2H	*Morrison-Knudsen, S & M, Paschen J.V.*	$86,493,975
7	*Damen to Roosevelt Connecting Structures*	75-120-2H	*Awarded to Various Contractors*	$19,877,570
8	*Roosevelt to Ogden Connecting Structures*	75-119-2H	*Awarded to Various Contractors*	$16,901,774
9	*Ogden to Addison Connecting Structures*	75-118-2H	*Awarded to Various Contractors*	$11,162,159
10	*Central to Damen Tunnel*	75-126-2H	*Healy, Ball, Horn J.V.*	$98,985,250
11	*Damen to Roosevelt Tunnel*	75-125-2H	*Paschen, Morrison-Knudsen, Kenny J.V.*	$107,837,300
12	*Roosevelt to Ogden Tunnel*	75-124-2H	*Shea Inc, P. Kiewit & Sons*	$101,970,680
14	*Ogden to Addison Tunnel*	75-123-2H	*Ball, Healy, Horn J.V.*	$85,205,910
15,16	*59th to Damen Connecting Structures*	73-163-2H	*Awarded to Various Contractors*	$26,440,052
17	*Mainstream Pumping Station Part I*	73-162-AH	*P.Kiewit & Sons, J F Shea, Kenny Cnstr J.V.*	$168,811,300
17	*Mainstream Pumping Station Part II*	73-162-BH	*Healy, Ball, Grow Tunneling Corp J.V.*	$64,755,000
17	*Mainstream Pumping Station Part III*	73-162-CH	*Morrison-Knudsen, Paschen Contractors J.V.*	$28,012,400
20	*Addison-Wilmette Connecting Structures*	73-058-AH	*Granite Construction Co.*	$34,966,450
20	*Addison-Wilmette Connecting Structures*	73-058-BH	*Granite Construction Co.*	$27,613,300
20	*Addison-Wilmette Connecting Structures*	73-058-CH	*Kenny, Paschen J.V.*	$19.571,740
20	*Addison-Wilmette Connecting Structures*	73-058-DH	*G H Ball Co, Dew & Sons J.V.*	$12,220,875

(1) Chronological order of awards
(2) Bid price

TABLE II (cont.)

TARP Phase I Contracts Completed

Ref. No. (1)	Project Name	Project Number	Contractor	Project Cost (2)
	Mainstream System (cont.)			
25	*North Branch Chicago River, Tnl & Conn Str.*	73-060-2H	*Perini, ICA, O&G J.V.*	$167,907,130
	Upper Des Plaines (O'Hare System)			
2	*Upper Des Plaines #20 Tunnel*	73-317-2S	*Healy, Ball, Greenfield J.V.*	$35,749,664
3	*Upper Des Plaines #21 Tunnel*	73-320-2S	*McHugh Construction Co.*	$21,371,607
4	*Upper Des Plaines #20B Tunnel*	73-319-2S	*Jay-Dee, Kenny J.V.*	$2,683,943
13	*Upper Des Plaines #20A Connecting Structures*	73-318-2S	*Jay-Dee, Jay-Dee of Illinois*	$4,598,650
	Calumet System			
5	*Crawford to Calumet Plant Tunnel*	73-287-2H	*Traylor Bros, Ferrera & Resco, Inc J.V.*	$79,256,370
18	*Calumet Tunnel And Pump Station*	74-206-2H	*Healy, Atlas-Gest International Inc J.V.*	$54,841,825
19	*Crawford Ave to Calumet Plant Connecting Str.*	73-273-2H	*S. A. Healy Co*	$19,173,509
24	*Calumet Tnl Sys,Tnl,Sfts,Con Str,140th St & Ind*	73-271-2H	*Kenny, P Kiewit, Shea J.V.*	$194,530,500
27	*Torrence Ave.Leg, Tunnels, Shfts & Conn Str.*	75-208-2H	*Kenny, P Kiewit, Shea J.V.*	$140,666,650
28	*Little Calumet Leg, Tunnels, Shfts & Conn Str.*	75-213-2H	*Jay-Dee, Affholder J.V.*	$168,700,000
	Des Plaines System			
21	*13A Ext.Tunnel,Shafts & Connecting Structures*	75-130-2H	*Kenny Construction Co.*	$23,292,759
22	*59th to Cermak,Tunnel,Shafts,& Connecting Str.*	73-164-2H	*Morrison-Knudsen, Paschen Contractors J.V.*	$156,631,000
23	*Cermak to Fullerton, Tnl, Sfts & Conn Struct.*	75-132-2H	*Impregilo, Ebasco, Losinger J.V*	$147,665,000
26	*Fullerton to Prairie, Tnl, Sfts & Conn Struct.*	75-131-2H	*Kenny, P Kiewit, Shea J.V.*	$141,120,000
			Total Phase I Contracts Completed:	**$2,332,154,822**

(1) Chronological order of awards
(2) Bid price

TABLE III
TARP Phase I Contract Remaining

12/1/10

Ref. No.	*Project Name*	*Project Number*	*Design Status*	*Project Cost (1)*
	Calumet System			
29	*O'Brien Lock Pumping Station*	*73-272-2H*	*Preliminary hydraulic studies completed*	*$62,352,000*
			Total Phase I Contracts Remaining	***$62,352,000***

TARP PHASE I SUMMARY	*Costs*
Phase I Contracts Completed (Table II)	*$2,332,154,822*
TARP Phase I Contracts Remaining (Table III)	*$62,352,000*
TARP Phase I Total Construction Cost	*$2,394,506,822*

(1) Estimated construction cost as of December 1, 2004

TABLE IV
TARP Phase II/CUP
U.S. Army Corps of Engineers Chicagoland Underflow Plan (CUP)

12/1/10

Project Name	*Project Number*	*Design/Construction Status*	*Project Costs (4)*	*Funded by USACE*
O'Hare Reservoir				
I - USACE Contract	*73-315-2S*	*Construction completed in 1998*	*$40,818,858*	*75%*
II - Betterments (1)	*93-339-2F*	*Construction completed in 1998*	*$3,991,694*	*No*
Thornton Reservoir				*See Note 3*
I - Vincennes Avenue Relocation	*77-235-AF*	*Construction completed in 2001*	*$4,398,000*	
II - Transitional Reservoir GW Monitoring Wells	*77-235-CF*	*Construction completed in 2002*	*$529,000*	
III - Transitional Reservoir (2)	*77-235-BF*	*Construction completed in 2003*	*$54,707,000*	
IV - Mining Agreement, Land Rights, and Corps Costs	*77-235-2F*	*Mining underway*	*$63,039,000*	
V - Tollway Dam and Grout Curtain	*04-201-4F*	*Under Construction*	*$84,084,000*	
VI - TARP Inlet/Outlet Tunnels and Gates	*04-202-4F*	*Under Construction*	*$148,975,000*	
VII - Final Reservoir Preparation	*04-203-4F*	*Construction to Begin in Jan. 2011*	*$60,987,000*	
VIII - Surface Aeration	*04-203-AF*	*Design in 2012*	*$4,200,000*	
McCook Reservoir				
I - Stages 1 and 2 - USACE Contracts	*73-161-2H*	*Reservoir to be constructed under several contracts Four contracts under construction, seven completed*	*$519,288,000*	*75%*
II - Expanded Stage 2 Betterment	*09-180-4F*	*Betterment to be constructed by expanding scope of several of the Army Corps contracts*	*$48,000,000*	*No*
III - Site Preparation, Lagoons 1-10	*73-161-BH*	*Construction completed in 2000*	*$889,000*	*$307,000 Credited*
IV - 73rd Street Tunnel Relocation	*97-156-2H*	*Construction completed in 2002*	*$15,132,000*	*Credited*
V - Willow Springs Berm	*96-249-2P*	*Construction completed in 2002*	*$3,593,000*	*No*
VI - Vulcan Primary Crusher Furnish and Deliver	*PO3030920*	*Crusher Purchased in 2005*	*$1,626,000*	*No*
VII - Conveyance Tunnel	*73-161-AH*	*Construction completed in 2006*	*$5,428,000*	*No*
VIII - Vulcan Mining Trucks and Loaders	*73-161-HH*	*Vehicles delivered in 2007*	*$11,105,000*	*No*
IX - Vulcan Miscellaneous Mining Vehicles	*73-161-GH*	*Vehicles delivered in 2007 and 2008*	*$6,200,000*	*No*
X - Conveyance System and Maintenance Facilities	*73-161-FH*	*Construction completed in 2008*	*$32,058,000*	*$1.75M Credited*
XI - LASMA Overburden Removal	*73-161-CH*	*Construction completed in 2010*	*$65,866,000*	*No*
XII - Vulcan Rock Mining Hard Costs Less Royalty	*73-161-EH*	*Mining underway*	*$29,690,000*	*No*
XIII - Stage 2 Misc. Overburden Removal	*73-161-JH*	*Under Construction*	*$7,052,000*	*No*
XIV - Expanded Stage 2 Overburden Removal	*73-161-DH*	*Construction to Begin in 2013*	*$23,000,000*	*No*
		Total Project Cost	*$1,234,656,552*	

(1) Betterment includes a control building, reservoir outflow control gates, and monitoring system.
(2) Cost shown is total cost of Transitional Reservoir. Facilities that will be re-used for the Thornton Composite Reservoir account for $30,337,000 of the cost.
(3) The District is advancing the design and construction of the Thornton Composite Reservoir in anticipation of receiving reimbursement from the Corps.
(4) Includes land, engineering, and construction costs.

ITEM 12

ITEM 12

ACCEPTABLE RISK LEVELS FOR PRIMARY CONTACT RECREATION

In 2004, EPA promulgated primary contact recreation criteria for coastal and Great Lakes beaches using a risk level of 8 per 1,000 illnesses for freshwater and 19 per 1,000 for marine waters. In August 2006, EPA issued a fact sheet that "addresses questions regarding the appropriate risk level (or levels) a state may choose when adopting into the state's water quality standards bacteria criteria to protect its coastal recreation waters." One of the most significant clarifications that EPA made was to state "there is no *a priori* reason to establish a higher level of protection for fresh waters than for marine waters. The difference in acceptable risk levels in the 1986 bacteria criteria document (8 illnesses per 1000 swimmers in fresh waters v. 19 per 1000 in marine waters) was based solely on the calculated risk levels for the previously recommended criterion of 200 fecal coliforms per 100 milliliter (ml), which were different in marine and fresh waters." EPA also clarified that states: [1]

> "could develop the data needed in freshwaters to establish in a scientifically sound manner the relationship between a 1.9% illness rate in freshwater and the corresponding concentration of indicator bacteria in their fresh waters; or they could develop the data needed in freshwaters to establish in a scientifically sound manner the relationship between an illness rate higher than 1% but less than 1.9% and corresponding indicator concentrations in freshwater."

To understand this better, it is helpful to return to the origins of the geometric mean criteria and risk levels. The geometric mean criterion for fecal coliform was established by a National Technical Advisory Committee (NTAC) to the Federal Water Pollution Control Administration. This committee examined epidemiological studies conducted in the 1940s and 1950s at three freshwater beaches (and a swimming pool) and one ocean beach. The criteria for selecting the beaches included "sanitary surveys indicated that the water quality was not subject to rapid fluctuation" (as with CSO and storm water discharges) and "areas were used frequently for swimming by residents of adjacent areas."[2] The committee established a statistical relationship of excess illnesses and total coliform using these studies for freshwater beaches. Excess illnesses were "detected" when the geometric mean density of total coliforms was greater than 2,300 per 100 ml[3]. The committee did not find a relationship at the marine beach.[4,5]

The geometric mean density of total coliforms was then translated into a fecal coliform density of 400 per 100 ml using Ohio River beach data from Dayton, KY. These data showed that, on average, 18% of the total coliform bacteria were fecal coliform. The NTAC established the geometric mean fecal coliform criterion for freshwater beaches by arbitrarily halving the 400 per 100 ml density to eliminate detectable risk (a hypothesis which was not tested).

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[1] EPA. 2006. Water Quality Standards For Coastal Recreation Waters: Considerations for States as They Select Appropriate Risk Levels. Office of Water. EPA-823-F-06-012. August 2006.

[2] Stevenson, Albert H. 1953. Studies of Bathing Water Quality and Health. Am. J. Public Hlth. Assoc. 43:529.

[3] National Technical Advisory Committee (NTAC). 1968. Water Quality Criteria. Federal Water Poll. Control Adm., Dept. of the Interior, Washington, DC.

[4] U.S. EPA. 1976. Quality Criteria for Water. Retrieved December 23, 2010. http://www.epa.gov/waterscience/criteria/redbook.pdf (at 86)

[5] Cabelli VJ, Dufour AP, Levin MA, McCabe LJ, Haberman PW. 1979. Relationship of Microbial Indicators to Health Effects at Marine Bathing Beaches. American Journal of Public Health. July, 1979, Vol. 69, No. 7: 690-696.

In 1969, EPA decided to evaluate whether the freshwater criteria should be revised, based on reports that the criteria were too restrictive. EPA designed a different epidemiological-microbiological program in 1972, with completion in 1979. "The objective of the program was to produce criteria, defined as a mathematical relationship of some untoward effect from swimming in sewage polluted water to the quality of that water as measured by any of a number of potential microbial or chemical indicators; thus, they were to be amenable to risk analysis."[6]

In 1976, while the epidemiological-microbial studies were being conducted, EPA adopted the 200 fecal coliform per 100 ml as a water quality criterion for bathing waters[4]. EPA noted the lack of epidemiological data to support a geometric mean criterion for marine waters but also noted that the occurrence of Salmonella in estuarine waters sharply increased at fecal coliform densities greater than 200 per 100 ml. This was the apparent rationale for adopting a fecal coliform criterion of 200 per 100 ml for both fresh and marine waters.

In 1983, EPA published its analysis from the epidemiological-microbiological studies for marine waters.[6] EPA established relationships between enterococcus and total gastrointestinal illness symptoms and highly credible gastrointestinal illness (HCGI) symptoms. The author of the report stated he favored:

> "the use of the criteria for HCGI symptoms because of the greater credibility of its data base and because it is more conducive to economic analysis. The 95 percent confidence limits for the regression lines as shown (Figure 9) are rather broad although the slopes are significantly different from zero. This was not unexpected since the relationships obtained are generalizations which may be altered by any of a number of temporal and spacial factors relative to the indicator, the pathogen, the relationship of the pollution sources to the bathing beach, the levels of the specific illnesses in the overall population, and the immune status of the swimmers." (Cabelli, 1983 at 41).

The author did not find a compelling statistical relationship between *E. coli* for marine waters, but did find a relationship for enterococcus. On Figure 9 of the report (page 43), the author showed a recommended criteria relationship between swimming-associated HCGI symptoms and mean enterococcus. At 19 illnesses, the geometric mean enterococcus is 35 colony forming units per 100 milliliters (cfu per 100 mL).

In 1984, EPA published its analysis of the epidemiological-microbiological studies for freshwater, relying heavily on the criteria document for marine waters.[7] EPA found relationships between E. coli and enterococcus for fresh waters. In comparing the results to the marine waters, EPA found that for the same geometric mean densities, the illness rates in marine waters were higher than those in freshwater. EPA hypothesized that the differences were due to differences in die-off rates of the indicator bacteria, stating:

"At equivalent indicator densities, there will be an excess of pathogen in marine waters relative to what would be found in freshwaters, and therefore a higher illness rate will be observed in marine waters. Thus, the difference in marine and freshwater swimmer illness rates

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[6] Cabelli VJ. 1983. Health Effects Criteria for Marine Recreational Waters. EPA Office of Research and Development. EPA-600 / 1-80-031. August 1983. (at iv)

[7] Dufour AP. Health Effects Criteria for Fresh Recreational Waters. EPA Office of Research and Development. EPA- 600 / 1-84-004. August 1984.

is not only statistically significant, but also is apparently compatible with many of the known characteristics of indicators and pathogens associated with the observed phenomenon. The significance of these findings is that a single water quality criterion for seawater and freshwater has been effectively eliminated from consideration and therefore a separate criterion should be used for each type of bathing water." (EPA, 1984, at 30)EPA used the results from the epidemiological-microbiological studies to establish new recreational use criteria in 1986. In the 1986 criteria document[8], EPA states that the acceptable illness rates for both marine (19 per 1000) and freshwater (8 per 1000) beaches are approximate and were established based on the fecal coliform geometric mean criterion of 200 cfu per 100 mL. EPA used Cabelli's 1983 report to establish the marine criterion for enterococcus of 35 cfu per 100 mL and Dufour's 1984 report to establish freshwater criteria for E. coli (126 per 100 ml) and enterococcus (33 per 100 ml). In a recent review of the selection of different "acceptable" risks for marine and fresh waters, a panel of experts found this selection of risk "to be an arbitrary decision that was not well founded."[9]

[8] EPA. 1986. Office of Water. Ambient Water Quality Criteria for Bacteria – 1986. EPA440/5-84-002. Retrieved December 23, 2010. http://www.epa.gov/waterscience/beaches/files/1986crit.pdf

[9] EPA. 2007. Report of the Experts Scientific Workshop on Critical Research Needs for the Development of New or Revised Recreational Water Quality Criteria. Proceedings from Workshop at the Airlie Center, Warrenton, VA. March 26-30, 2007. Office of Water, Office of Research and Development, June 15, 2007. (at 96).

ITEM 13

LETTER OF AGREEMENT

Between

Water Environment Research Foundation (WERF)
635 Slaters Lane
Alexandria, Virginia 22314

and

Metropolitan Water Reclamation District of Greater Chicago (District)
100 East Erie Street
Chicago, Illinois 60611-3154

Purpose of Letter of Agreement (LOA)

The purpose of this LOA is to describe the parties' roles and responsibilities and the funding arrangements for the Peer Review of the study entitled "Epidemiologic Study of Recreational Use of the Chicago Area Waterways" to examine public health risk from exposure to pathogens in the Chicago Area Waterways (CAWs)as a result of secondary contact recreation. The objectives for this research are to

1) determine rates of acute gastrointestinal and non-gastrointestinal illness attributable to recreation on the CAWs,
2) define the relationship between concentrations of microbes in the CAWs and rates of illness among recreators,
3) identify pathogens responsible for acute infections among recreators, and explore sources of those pathogens on the CAWs, and
4) provide the data and analysis to potential end-users and decision makers in order to strengthen the science used on both local and national scales to the extent possible.

Roles and Responsibilities of the Parties

The parties to this agreement are WERF (and its peer review committee) and the District (and its UIC research team).

The Role and Responsibility of WERF and its Peer Review Committee

WERF's role is to provide expert objective oversight of the epidemiological study. In that role, WERF will

- Assemble an objective peer review committee, consisting of volunteers with appropriate expertise and perspectives,
- Make travel and meeting arrangements for the peer review committee,
- Orchestrate collection, compilation and sharing of peer review comments and research team responses,
- Serve as liaison between the peer review committee and the research team and the

District, and.

- Serve as the liaison between the District study and pertinent work on WERF's microbes research challenge and other efforts to maximize leveraging of research outcomes and opportunities.

Charge to the Peer Review Committee:
The Peer Review Committee is being asked to evaluate the study scope and design and to provide objective input and oversight over the course of the project to ensure that the study is as scientifically sound and statistically supportable as all involved can make it. To that end, the committee is being asked to:

- Review and provide input on the program scope and study design. Ensure that approaches are scientifically sound and statistically powerful.
- Review and provide feedback on the QAPP for the study, including sampling plan (and spatial and temporal distribution) and interview approaches.
- Provide peer review oversight and direction as the study progresses.
- Provide peer review insight on final products (journal articles, other reports)

WERF and the District will attempt to keep the amount of extracurricular reading and other work required for the committee to a minimum, although the committee will be expected to read and comment upon pertinent materials prior to the peer review meetings, and at critical junctures in the research process. These meetings will be scheduled to coincide with critical junctures, including a kickoff meeting early on to involve the peer reviewers and to allow opportunities to refine the study design, work plan and QAPP.

Please note that WERF will not seek consensus by the peer review committee, but will seek to facilitate discussion and resolution in instances where peer review comments may be in conflict with one another, so that the comments provide constructive direction.

The Role and Responsibility of the District and the UIC Research Team
As sponsors and investigators of the study, respectively, the District and the UIC research team will be responsible for addressing all comments received from WERF on behalf of the Peer Review Committee. If there are comments that are deemed not actionable, that is, the investigators do not believe the suggested actions or changes are warranted, or factors such as budget constraints (the Board of Supervisors will need to approve any additional expenditures), specific responses to the comments will be provided to the committee through WERF. Otherwise, the suggested actions or changes will be reflected in the research project. Final products will acknowledge and reflect input from WERF and its Peer Review Committee.

The District will also assemble and coordinate a local stakeholder advisory workgroup and will work with WERF to coordinate the input of both committee groups. The local advisors will work primarily with the District and the research team, but may on occasion interface with the Peer Review Committee. The format for this involvement remains to be agreed upon.

Tentative Project Schedule:
The following outlines a tentative schedule of key items and milestone dates for the project. Specific dates will be determined for review activity as project scope is firmed up.

Date	Item/Task
June 2007	Distribute papers to Peer Review Committee for Review
July 2007	Tentative date for kickoff meeting with Peer Review Committee
August 2007	Research Team has incorporated comments and suggestions into applicable aspects of study
August 2007	Initiation of Study
Fall 2007	Research Team to report outcomes of fall work to Peer Review Committee, and round of review/revisions prior to spring recreational season. Analysis of field data through the winter Specific dates for interface with Peer Review Committee to be determined
Spring-Fall 2008	Further field work to be conducted on epidemiology study
Spring 2008	Placeholder for 2nd meeting of the Peer Review Committee
Summer 2008	Placeholder for Peer Review Committee to review progress and direction of study
Fall 2008	Research Team to report outcomes of 2008 field work to Peer Review Committee, and round of review/comment as data are analyzed. Analysis of field data through the winter Specific dates for interface with Peer Review Committee to be determined

Study Completion dates and final review meeting to discuss findings, products and report(s) to be determined.

Budget:
WERF's Board has approved up to $25,000 to cover the travel, food and lodging for members of the volunteer Peer Review Committee.

The District's Board has approved funding to conduct the overall study, and has approved WERF to provide the peer review services.

Indemnification:

This section has been intentionally left blank.

Agreement:
Both parties mutually agree to accept the conditions described in this LOA. Any amendment to this agreement shall be in writing and mutually agreed to by WERF and the District.

WATER ENVIRONMENT RESEARCH FOUNDATION	METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
DMWoltering	R Lanyon
Daniel M. Woltering, Ph.D., Director of Research	Richard Lanyon, General Superintendent
Date 9-11-07	Date 9/4/07

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* * * * * PC# 565 * * * * *

ITEM 14

ITEM 14

RECENT STUDIES RE CHILDREN AND PRIMARY CONTACT RISKS

EPA is conducting scientific research to support new primary contact recreational use criteria for coastal and Great Lakes beaches. One of EPA's goals for this research is to assess "potential human health risks (including non-gastrointestinal effects) in the general population, including children, from swimming-related exposure to different sources of fecal contamination (human versus non-human)"[1]. EPA has published four studies where they conducted statistical analysis of epidemiological study data regarding risk of illness to children from primary contact recreation at beaches; this analysis is referred to as project P29. Additional research has also been conducted by others on this topic. Results from recent EPA and other studies are summarized below.

These studies have not resulted in definitive statements that different primary contact criteria would be more, or less, protective for children. Further, EPA has not, to date, addressed the potential issues associated with bathers, and in particular children, being a source of individual organisms and pathogens to recreational waters. This was one of the recommendations made at an experts' workshop in 2007[2]. Instead, it may be more appropriate to establish beach and recreational water management practices rather than separate recreational use criteria[3]. Finally, it should be noted that results of these studies cannot be extrapolated to risks associated with secondary contact recreation because of significant differences in exposure and ingestion rates.

Four Freshwater Great Lakes Beaches Studies[4]

EPA conducted interviews with beachgoers at four freshwater beaches in 2003 and 2004. In 2003, studies were conducted at West Beach (on Lake Michigan in Indiana Dunes National Seashore in Indiana) and Huntington Beach (on Lake Erie near Cleveland, OH). In 2004, studies were conducted at Silver Beach (on Lake Michigan near St. Joseph, Michigan) and Washington Park Beach (on Lake Michigan in Michigan City, Indiana). "Swimming" was defined as people who immersed their body at least waist-high, regardless of whether they ingested water.

The purpose of these studies was to confirm that a rapid test method, specifically enterococcus qPCR calibrator cell equivalents (CCEs), could be positively associated with swimming-associated gastrointestinal (GI) illness. In confirming this relationship, EPA researchers stated that the association between GI illness and qPCR CCE was stronger among children (aged 10 years and below). A critique of the paper noted, along with several other observations, that EPA's statistical relationships calculate that children are at less risk than the general population when enterococcus qPCR CCEs were below 27. In response to the critique,

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[1] EPA. 2007. Critical Path Science Plan for the Development of New or Revised Recreational Water Quality Criteria. Office of Water, Office of Research and Development. August 31, 2007. (at 1-4).

[2] EPA. 2007. Report of the Experts Scientific Workshop on Critical Research Needs for the Development of New or Revised Recreational Water Quality Criteria. Proceedings from Workshop at the Airlie Center, Warrenton, VA. March 26-30, 2007. Office of Water, Office of Research and Development, June 15, 2007. (at 89).

[3] During the October 6-7, 2009 stakeholder meeting for EPA's Development of New or Revised Recreational Criteria (Chicago), expert panelists, Dr. Samuel Dorevitch, Assistant Professor at University of Illinois at Chicago, and Mr. Lyman Welch, Water Quality Program Manager at the Alliance for the Great Lakes, recommended promoting behavior change and public education as a measure to protect sensitive populations.

[4] Wade T.J., Calderon RL, Brenner K.P., et al. 2008. High sensitivity of children to swimming associated gastrointestinal illness: results using a rapid assay of recreational water quality. *Epidemiology*. 2008;**19**:375–383.

the authors stated "[W]e do not suggest that "the sensitivity of children warrants adjustment of recreational water quality criteria."[5]

Three Marine Beach Studies[6]

EPA continued its research to determine if qPCR could be used to establish a relationship between fecal indicator bacteria and illness. The three beaches were located within 7 miles of disinfected effluent discharged from a publicly owned treatment works (POTW) serving a population of at least 15,000. In 2005, EPA studied Edgewater Beach (Gulf of Mexico in Biloxi, Mississippi) and in 2007, studied Goddard Beach (Greenwich Bay in Goddard Memorial State Park in West Warwick, Rhode Island) and Fairhope Municipal Beach (a bay in the Gulf of Mexico in Fairhope, Alabama). Each site showed variability in fecal indicator bacteria, but samples were "generally in compliance with local and federal water quality guidelines" (Wade, 2010, at 2).

EPA confirmed that rapid, molecular measures of water quality can be used to assess illnesses among swimmers at marine beaches in temperate climates with nearby treated sewage discharges. EPA also analyzed data associated with children less than 10 years old and found "no evidence of an increased susceptibility to illness with exposure to fecal indicator bacteria. Statistical models which allowed a separate slope for children showed no improvement over models with a single slope for all subjects." (at 6).

Studies in Marine Waters Impacted by Urban Runoff[7]

EPA also agreed in its court settlement to investigate whether qPCR could be used to establish illnesses at a marine beach primarily impacted by urban runoff for children and the general population. In 2009, EPA conducted an epidemiological study at Surfside Beach (Atlantic Ocean, South of Myrtle Beach, South Carolina). EPA found that "[n]o statistically significant linear associations were observed between the incidence of illness and exposure to Enterococcus CFU among swimming children" (EPA, 2010, at 76). "Non-significant trends were seen between GI illness and diarrhea and Enterococcus CCE", for both the general population and children (at 85).

Studies in a Tropical Region[6]

EPA also agreed to investigate whether qPCR could be used to establish illnesses for children and the general population at a tropical marine beach (impacted by treated POTW effluent). In 2009, EPA conducted epidemiological studies at Boqueron Beach in Puerto Rico. EPA indicated that good water quality and interference of the qPCR assays prevented EPA from evaluating whether a relationship between illness and enterococcus existed (EPA, 2010, at ii).

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[5] Letters to the Editor re: High sensitivity of children to swimming associated gastrointestinal illness. Epidemiology: January 2009 - Volume 20 - Issue 1 - pp 156-157, doi: 10.1097/EDE.0b013e31818f2f56

[6] Wade T.J.(wade.tim@epa.gov) et al. 2010. Rapidly measured indicators of recreational water quality and swimming-associated illness at marine beaches: A prospective cohort study. *Environmental Health* 2010, 9:66 doi:10.1186/1476-069X-9-66, ISSN 1476-069X http://www.ehjournal.net/content/9/1/66

[7] Wade, T.J. et al. 2010. Report on 2009 National Epidemiologic and Environmental Assessment of Recreational Water Epidemiology Studies. EPA, Office of Research and Development, EPA Report Number: EPA/600/R-10/168