Combined Sewer System Modeling Work Plan

Albany Pool
Part B Long-Term Control Plan

Prepared for:
Capital District Regional Planning Commission (CDRPC)

Prepared by:
Albany Pool Joint Venture Team

September 2007

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Section 1
Purpose

This Combined Sewer System Modeling Work Plan describes the approach that will be taken to model the interceptors, key trunk sewers, regulators, overflows and other key appurtenances within the Albany Pool communities' combined sewer systems. The work plan was prepared in accordance with the conditionally approved Scope of Work and Combined Sewer System Monitoring and Modeling Plan dated February 2007. This Plan defines the activities to be performed under Task B.5, Combined Sewer System Modeling.

The Albany Pool communities have 92 combined sewer overflows (CSOs) that discharge to the Hudson and Mohawk rivers. To develop a plan for limiting these discharges, the City of Troy, City of Albany, City of Cohoes, City of Rensselaer, City of Watervliet and the Village of Green Island (the *"Pool"* communities) have joined in a comprehensive inter-municipal venture, led by the Capital District Regional Planning Commission (CDRPC), to develop a Phase I Long Term Control Plan (LTCP).

Sewer system models will be developed to characterize the behavior of the combined sewer systems, quantify CSO discharges and evaluate CSO control alternatives. The models will predict existing pollutant loads discharged during CSO events and evaluate impacts that may result from future development, improvements to the sewer system, and changes in maintenance and operational procedures. This effort will directly contribute to the reduction of CSO discharges that may impair water quality and affect contact recreation and habitat in the Class C waters of the Hudson and Mohawk rivers.

The Pool communities are served by three wastewater treatment plants (WWTPs):

- Albany County Sewer District (ACSD) North Plant
- Albany County Sewer District South Plant
- Rensselaer County Sewer District (RCSD) Plant

The models will simulate the behavior of the combined and sanitary flows through RCSD and ACSD interceptor sewers, selected trunk sewers, regulators and overflows. Three distinct models are planned. Three modeling teams will be established to complete the effort. It may be appropriate to divide the RCSD system into distinct models for Troy and Rensselaer. This decision will be made once hydraulic conditions at the WWTP have been further analyzed.

Section 2
Modeling Approach

2.1 Software

Collection system models using USEPA SWMM 5 (Storm Water Management Model) will be developed for the sewers tributary to each WWTP to facilitate analysis of CSO statistics and aid system improvement planning. Each model will be developed using USEPA SWMM 5.0.9 or a more recent release of the software. The consultants will ensure the models' complete compatibility with the selected SWMM 5 version and with each other.

Pipe hydraulics will be simulated using SWMM's dynamic wave solution (called "Extran" in earlier SWMM versions). The model accounts for channel storage, backwater, form losses, flow reversal, and pressurized flow.

The models will not simulate water quality. Overflow loads to receiving waters will be characterized using event-mean concentration data obtained from the monitoring program and flows computed by the models.

2.2 Hydraulic Network

Extent

The sewer system models will extend along a 12-mile length of the Hudson River, including the ACSD and RCSD interceptor sewers, and all CSO regulating structures and overflow points. The hydraulic network of each model will generally begin one pipe segment above each combined sewer regulator. Long runs of principal sewers upgradient of modeled regulators will also be included, but with limited detail. These trunks sewers will typically extend up to one-half the length of the contributing system. Physical characteristics of modeled trunk sewer extensions will be estimated. No survey will be conducted in these areas.

Boundary Conditions

The models will be bounded at the WWTPs and at CSO regulators. Each model will terminate at or near the entrance to its WWTP with a flow constraint or other appropriate boundary condition. Hydraulic boundaries at certain CSO regulators will be modeled as free discharges. In cases where river stage frequently influences sewer system hydraulics upgradient of regulators, the model may be extended to include the overflow pipe and a time-series boundary representing river level. River levels upstream of Federal Dam at Troy will be assessed using 15-minute levels from USGS gage 01358000 at Green Island. River levels in the tidal waters of the Hudson River below the dam will be assessed using tide predictions published by the National Ocean Service for station 8518995 at Albany.

Level of Detail
The hydraulic networks may exclude manholes in straight runs of pipe to maintain parsimony and limit data collection needs. Depending on actual geometry, multiple pipe segments may be aggregated to runs of 500 to 1000 feet at the modelers' discretion. Changes in pipe shape and slope will be maintained.

The hydraulics of principal control structures, including gates, weirs, and pumps, will be directly modeled wherever practical. Known significant sediment accumulations in the sewers will be represented in the models as partially filled pipes.

Datum
The models will use a common vertical datum (e.g. feet, NAVD 88) and a common geodetic reference system (e.g. NAD 1983 New York State East). All manholes will be georeferenced, although modelers may shift manhole locations, typically by up to 50 feet, to facilitate visual display. Significant bends in pipes will be included for display purposes and to maintain reasonably accurate lengths.

Naming
Naming conventions for manholes will be based upon any existing standards in each Pool community. Where no conventions exist, a consistent and sensible naming convention will be developed using a code of 10 characters or less. For instance, the name codes might include an initial letter for the sewer owner, a four-letter code for a street name, and a 5-digit number representing stationing or a randomly generated name. Where names must be created for pipes, each pipe will have the same name as its upgradient manhole. Where more than one pipe exits a junction, the respective pipe IDs will be assigned numeric suffixes, e.g. TMain60272:1 and TMain60272:2. Pump, weir and orifice links will be suffixed with PU, WR, and OR, or other appropriate identifiers.

Parameter settings
Pipe roughness (Manning's N) will initially be uniformly set at 0.013. Values may be adjusted within accepted engineering standards during calibration. Form losses will only be explicitly represented at major structures.

Manhole inverts will be interpreted from sewer system maps, record plans, and survey data. Manhole rims will be estimated based on topographic data and supplemented with survey data in key locations.

2.3 Hydrology

The hydrologic models will represent the full sewer service areas contributing to the WWTPs in the Pool communities. Contributing areas from non-Pool communities will be represented with the minimum level of detail needed to reasonably model their sanitary sewage and inflow/infiltration contributions to Pool combined sewer collection systems.

Combined sewer catchments

Stormwater runoff will be modeled using SWMM's rainfall-runoff module. Where the hydraulic extent of the model connects to surface water inflow points, approximately one catchment per manhole will be delineated based on sewer network data and digital elevation data. Areas upgradient of the hydraulic model extent will be divided into multiple drainage catchments as appropriate, while manholes along interceptors with no service connections will not have corresponding catchments. Initial imperviousness area fractions will be assigned based on data obtained during the cost allocation activity performed in Part A.

Separate sewer catchments

Separate sanitary sewersheds in Pool communities and other communities contributing sewage to the Pool collection systems will be accounted for in the models. Scaling factors will be used to reduce sanitary sewershed areas to values representative of the area contributing rainfall-dependent inflow to the sewer systems. Sanitary sewersheds will otherwise be represented in the same manner as combined sewersheds. If any separate stormwater pipes merge with the combined sewer system within the area of the model's detail, both sanitary and storm catchments will be represented for an area.

Sanitary flows

Sanitary flows will be modeled using diurnally varied hydrographs for each catchment. Sanitary flows will be apportioned to individual drainage catchments based on flow data, water consumption data, land use and/or population. Unmetered areas receiving sanitary flow will be compared to areas where flow metering data is available to estimate base infiltration. Infiltration will be modeled as a seasonally varied rate based upon available historical data. Each load point will be assigned distinct values for average sanitary flow and average infiltration. Sanitary flows will generally be loaded at the same locations as catchments.

CDRPC predicts a 2% population decline in the six Pool communities from 2007 to 2040 (statistics accessed at www.cdrpc.org/Proj-Pop.html). Growth of 0.3% and 4% is predicted for Albany and Green Island respectively, while population declines ranging from 3% to 6% are predicted for the other communities. Because these population changes are small and their correlation with total water use is difficult to predict, the calibrated existing condition sanitary flows in the models will not be changed for future condition baseline and alternatives simulations.

Snow Processes

Snowmelt processes will not be directly modeled. The models will simulate snowfall as liquid precipitation. This approach does not require the integration of temperature effects, and assumes that snow enters the sewer system as equivalent rainfall.

Catchment Parameters

Manning's roughness coefficients (N) for overland flow will be set to uniform values for impervious and pervious areas respectively. Depression storage will be similarly fixed at uniform values for impervious and pervious areas respectively.

A standard infiltration method such as Green-Ampt or Horton will be used for pervious area runoff calculations. All the models will use the same method. A limited number of soil types will be established unless robust data supporting differentiation of these parameters exists. There is often little value in differentiating soils in urban areas. Runoff from impervious areas greatly exceeds runoff from pervious areas, and soil surveys often describe urban soils as "disturbed" and do not assign them specific infiltration characteristics. Soil survey data for Albany and Rensselaer counties will be obtained from the Natural Resources Conservation Service website accessible at websoilsurvey.nrcs.usda.gov.

Section 3
Model Calibration

3.1 Overview

Calibration is the process of adjusting model parameters within reasonable and consistent limits so that results reasonably match measured values. The models will be calibrated based on flow metering data obtained during this study and additional pertinent information. The models will be calibrated for dry weather flow, wet weather flow and a multi-month continuous simulation. The model will be validated using a long-term simulation of up to a year and stress tested for extreme event(s).

Monitoring 10 to 20 percent of the CSO regulators in a system generally provides a robust dataset for calibrating collection system models to represent CSOs across the entire system. Between 70 and 90 percent of total CSO is attributable to these principal regulators in many CSO systems. Flow metering locations will be defined based on the team's understanding of the system configuration, preliminary CSS modeling results, and block testing data collected by the pool communities. Block testing data collection will begin in the fall of 2007. Consistent with the conditionally approved Scope of Work and Combined Sewer System Monitoring and Modeling Plan dated February 2007, detailed flow and precipitation-monitoring protocols will be further defined and presented in the Combined Sewer System Monitoring Plan due February 1, 2008.

The flow-monitoring program will include four continuously recording rain gages. Prior to model calibration, the rainfall data's spatial and temporal variability will be assessed to determine if observed differences in rainfall hyetographs among the project gages might limit the validity of model calibration. If high variability is found in the measured data, then radar data collected by National Weather Service satellites and the field-measured rain data will be integrated by Vieux, Inc. to model high-resolution synthetic rain gages. The synthetic rain gage network would be developed at a grid density of up to one square kilometer for discrete storms calibration.

After completion of the flow monitoring data quality assurance and quality control, the consultant team will work with the Pool communities and NYS DEC to develop mutually acceptable calibration guidelines. The degree of model calibration will be evaluated by both quantitative and qualitative comparisons of model predictions with the field measurements. Calibration guidelines will be tailored to the quality of observed flow, depth, and rainfall data. As a starting point, calibration guidelines will be based on standards such as those promulgated by the UK Wastewater Planning Users Group (WAPUG) Code of Practice for the Hydraulic Modeling of Sewer Systems (2002) and USEPA's Combined Sewer Overflows: Guidance for Monitoring and Modeling (1999). Sensitivity analyses of the calibrated model parameters will be performed to quantify the models' accuracy.

3.2 Dry Weather

A three-day period of dry weather flow will be analyzed in detail to examine diurnal flow patterns and hydraulic grade lines in the sewers. The models will be judged against the following metrics:

- Timing of peaks and troughs
- Diurnal peak flow rates
- Average and peak depth
- Average and peak velocity
- Volume

Dry weather calibration goals may not be met for all cases for a variety of reasons, including meter malfunction, system repairs, system blockage, etc. Vagaries of monitoring conditions may necessitate use of different dry weather days within each model and may require that the days not be consecutive. When calibration goals cannot be met with reasonable parameter adjustments, reasons for discrepancies will be identified.

3.3 Discrete Storms

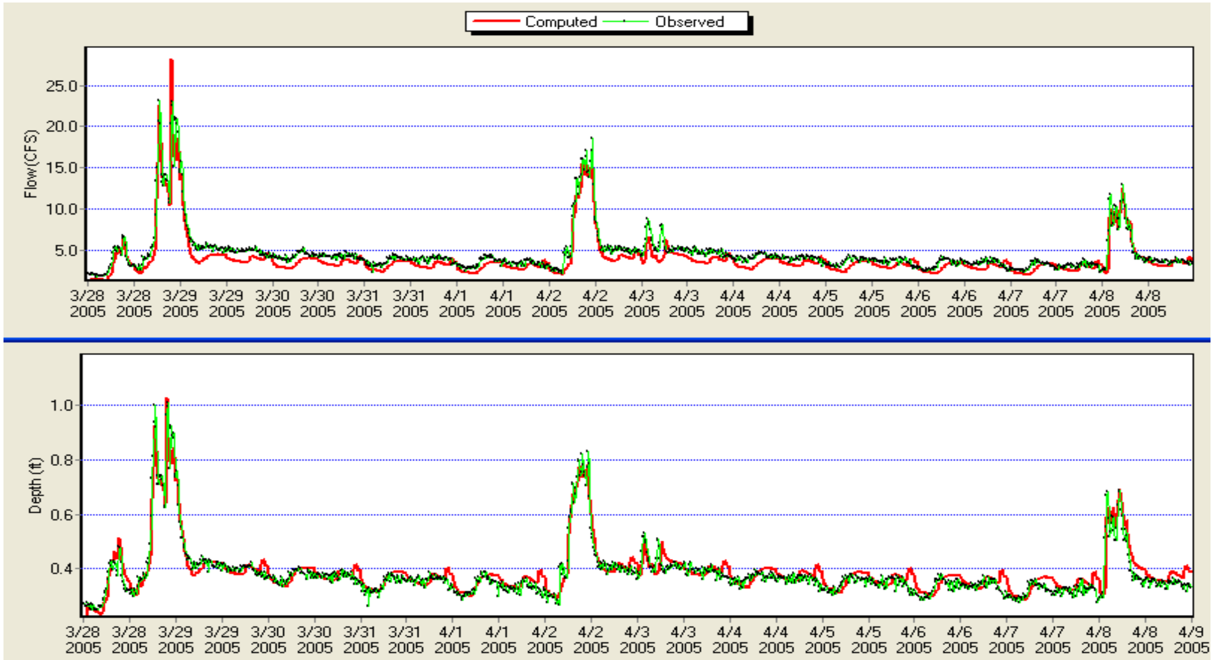
The models will be calibrated using data collected for three storms during the metering period with reliable flow monitoring data. To the extent practical, each model will use the same storm events for calibration. Flows and depths estimated by the models will be compared to observed values. The following metrics will be assessed:

- Timing of peaks and troughs
- Peak flow rates at each significant peak
- Depth
- Peak velocity
- Volume

Wet weather calibration goals may not be met for all cases for a variety of reasons, including meter malfunction, system repairs, system blockage, etc. The complexities of collecting reliable flow data and the vagaries of weather conditions may necessitate use of different storm events within each model. When calibration goals cannot be met with reasonable parameter adjustments, reasons for discrepancies will be identified.

Time history calibration plots will be prepared for each principal storm at each selected calibration flow meter. It may be appropriate to prepare one graph for closely spaced storms as in the example in Figure 3-1 below:

Figure 3-1. Example Time History Calibration Plots



The modeling team has found that three events for model calibration are typically adequate to demonstrate and assure proper model operation.

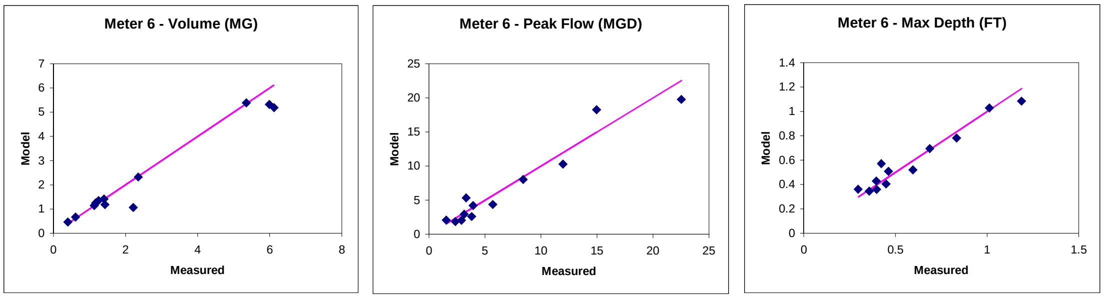
3.4 Wet Weather Calibration using Multi-month Analysis

The models will be run continuously for the duration of the summer 2008 metering program to assess their performance across a range of storm sizes. Model results will be judged against the following metrics:

- CSO activation frequency, duration, and volume as compared with available metering data
- Flow volumes for each meter site for each storm
- Peak discharge for each meter site for each storm
- Peak depth for each meter site for each storm
- Peak velocity for each meter site for each storm

Plots comparing measured and modeled peaks and discharge volume for all storms will be prepared for each meter as in the example shown below in Figure 3-2:

Figure 3-2. Example Calibration Event Scatterplots



In the graphs above, each dot corresponds with measured and modeled values for one storm. The pink line marks ideal one-to-one correspondence.

The modeling team believes that multi-month continuous simulation is more effective than calibration or validation to additional single events, as it uses key measurements from all monitored storm events without introducing a large burden of qualitative assessment of additional time series plots.

3.5 Validation

The models will be run for up to one year to ensure that they adequately simulate CSO statistics and seasonally varied phenomena. The following metrics will be used:

- Block testing statistics
- Daily flow volumes and flow exceedance frequency statistics at WWTPs

Block testing data collected by the communities will be used to check and validate the overflow frequency predicted by the models against these data. Tables such as shown in the example below will be prepared to assess the number of observed and simulated overflow events and adjust model parameters to achieve a reasonable fit. Table 3-1 below helps identify storms where overflows may have been falsely simulated at multiple CSOs, or, conversely, where CSO measured for an event is not reproduced by the model. A summary version of this table, showing only observed and simulated event counts, will be presented in the model calibration memorandum, as the large number of CSOs in the system would make a more detailed table tedious to review.

Table 3-1. Calibration against Block Testing Example

	5/7/08	5/15/08	5/30/08	6/11/08	6/17/08	6/29/08	Observed	Simulated
CSO1		S		O	OS		2	2
CSO2			OS	O	OS		3	2
CSO3	OS	S		O	O	O	4	2

OS - Overflow observed and simulated

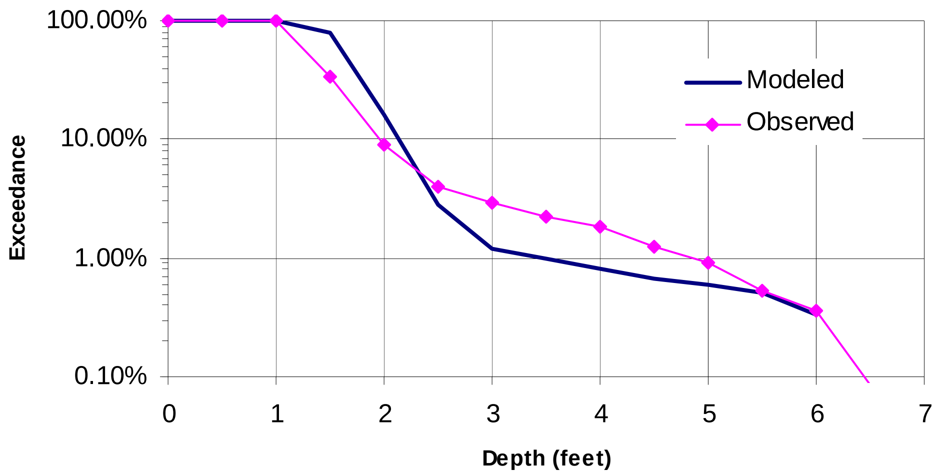
S - Simulated overflow not observed

O - Observed overflow not simulated

blank - Overflow neither observed nor simulated

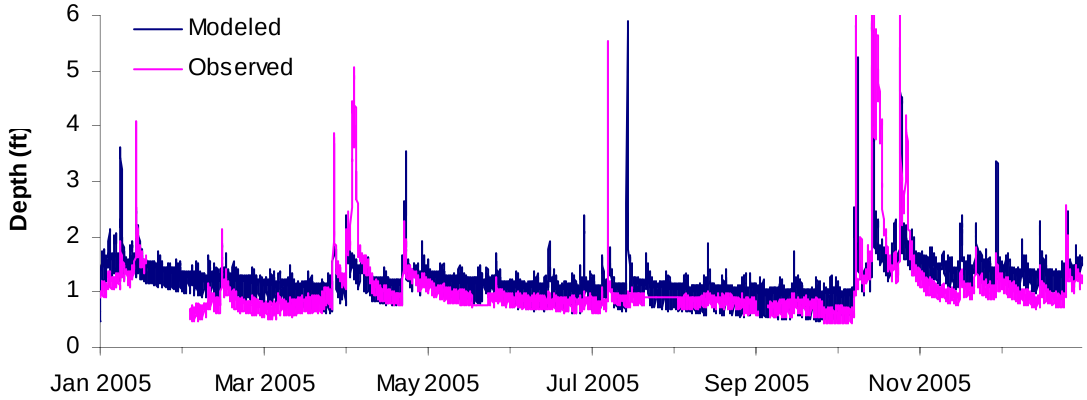
Graphics showing long-term frequency distributions of flows or depths will be prepared at key locations where long-term data is available, such as at WWTPs and major pump stations. Such graphs help identify the overall validity of the range of flows simulated in the model. An example is shown in Figure 3-3.

Figure 3-3. Example Long-term Depth Frequency Distribution Plot



Time series of long-term flows may also be prepared to assess the models' long-term performance, such as in Figure 3-4.

Figure 3-4. Example Long-term Depth Time Series Calibration Plot



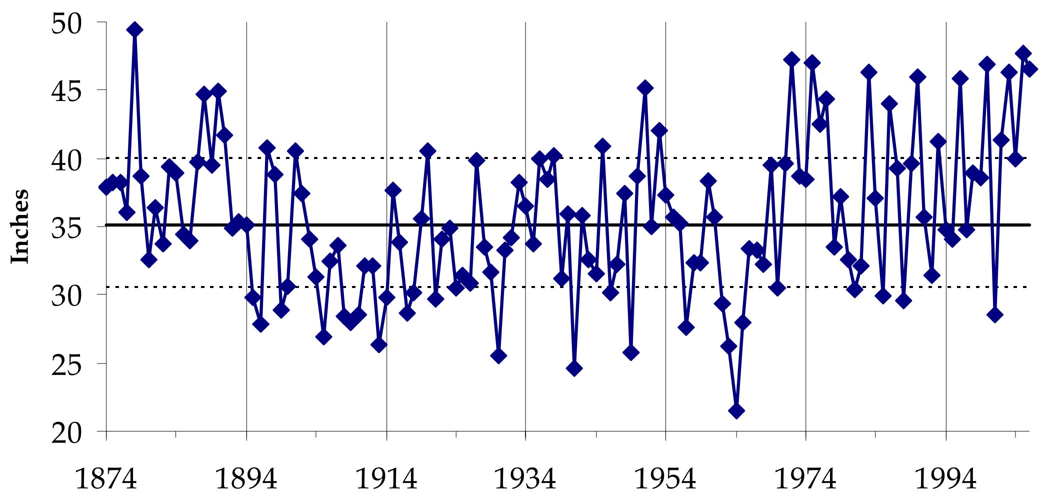
The models will be stress-tested to ensure they produce sensible results for storms larger than those occurring during the calibration period. Candidate events for this analysis are Hurricane Floyd on September 16-17, 1999, when six inches of rain fell at Albany Airport in 31 hours, and a storm possibly related to Hurricane Charley on August 15, 2004, when 2.5 inches of rain fell in nine hours with 1.9 inches in the peak three hours.

Section 4
Precipitation Data Selection Procedures

4.1 Available Data

For calibration of the metering program data, precipitation data from project rain gages will be used. For long-term simulations, including model validation, hourly precipitation data from Albany International Airport will be used. National Weather Service meteorological data for Albany were identified to assess their applicability to the LTCP. Complete digital hourly precipitation data for Albany is available from May 1948 to the present. The only period of missing hourly data is from April through June 2002. Daily records of precipitation and temperature are available for 1874 to the present. Albany hourly precipitation data may be synthetically disaggregated to 15-minute intervals using a stochastic algorithm incorporated into

Figure 4-1. Albany Annual Precipitation



the NetSTORM rainfall analysis software (software description and references at www.dynsystem.com/netstorm.) This may allow better representation of short-duration high-intensity rainfall than is possible with hourly data.

Figure 4-1 shows annual precipitation recorded at Albany from 1874 through 2006. Average annual precipitation was 35.6 inches, with a median value of 35.1 inches, and 20th and 80th percentiles of 30.5 and 39.9 inches.

4.2 Use of Representative Period

The detailed hydraulic and hydrologic models will be run for a five-year representative period. This is a more rigorous method than the "typical year" approach used in many CSO studies. It follows the approach the modeling team has used in numerous communities for modeling in support of long-term control plans. Running detailed combined sewer system hydraulic models for periods longer than five years is generally impractical, and would yield minimal useful information that cannot be obtained from a one or five year simulation. At the same time, careful considerations will be given to selecting a representative five-year period by applying a simpler NetSTORM model to evaluate the available long-term precipitation dataset for Albany area as described in section 4.3. Since CSO control strategies generally aim to limit CSO to recurrence frequencies of up to one year, a five-year simulation where CSO discharges five times, corresponding with one-year control, provides a statistically sound basis for predicting system performance.

Statistics will be developed to identify average annual CSO volume, duration, and frequency at each outfall. Additionally, one-month, three-month, six-month, one-year, two-year, and five-year overflow volumes and peak overflow rates will be computed. The one-month through one-year statistics will be extracted directly from the model output statistics. For example, the one-year peak CSO discharge rate would be the fifth largest simulated discharge rate occurring in the five-year simulation, and the six-month discharge would be the 10th largest discharge rate. Two- and five-year CSO statistics will be computed by fitting the computed peak discharges and volumes to statistical distribution functions to adjust for the limited number of large storms that would be used to characterize the extreme flows. This approach can be preferable to using a single design storm as it inherently accounts for the likelihood that the same storm may not produce both the "n"-year peak discharge and the "n"-year CSO volume.

4.3 Selection Methodology

Three scoring systems will be applied to rate each five-year period in the 59-year record from 1949 - 2006:

- The recurrence intervals of precipitation events at 3-hour duration within each five-year period are ranked. Periods that have close to the ideal number of events at 1-week to 1-year events receive the highest scores. The ideal five-year period would have 260 1-week events, 130 2-week events, 60 1-month events, 20 3-month events, 10 6-month events, and 5 1-year events. A 3-hour duration corresponds with a typical time of concentration for Pool sewer systems.

- Recurrence intervals of estimated CSO volumes by storm within each five-year period are ranked using a simple NetSTORM model of system-wide CSO. Periods that have close to the ideal number of events at 1-week to 1-year events receive the highest scores. Simulated CSO events are ranked according to their total volume. For example, the 58th largest CSO volume for a single storm in the simulation is considered the 1-year CSO event, while the 696th largest event is considered the 1-month event (696 = 58x12). The ideal five-year period would have 260 1-week events, 130 2-week events, 60 1-month events, 20 3-month events, 10 6-month events, and 5 1-year events.

- Annual average precipitation and annual average CSO volume for each five-year period is ranked. The ideal five-year period would have average annual precipitation and average annual CSO matching long-term means.

This method ensures that the selected five-year period has nearly average precipitation and CSO. It should include one wet year (CSO more than one standard deviation above average), one dry year, and one nearly average year. The selected contiguous five-year period should provide the best overall fit to the above criteria and exclude any storms with return periods greater than 10 years at durations from 1 to 24 hours.

Section 5
Baseline Simulations and Alternatives Analysis

The calibrated models will be adjusted to reflect principal existing planned changes to the sewer systems that are appropriate for inclusion in a baseline simulation, such as proposed sewer system projects or major new developments. The models will then be run for a five-year simulation to obtain average annual CSO statistics at each CSO regulator.

The models will include each CSO regulator and will simulate outfall-specific CSO discharges. The most useful tool for estimating loadings is the event mean concentration (EMC). EMC is the total mass load of a pollutant yielded from a site during a storm divided by the total water volume discharged during the event. Event-mean concentrations for both the wastewater and stormwater fractions of these overflow volumes will be developed for the constituents of interest. Local sampling data provides the most reliable data source for the wastewater fraction. Large national stormwater quality datasets provide the most reliable data source for the stormwater fraction. The load for each fraction is computed as the product of the volume and the event-mean concentration, and these fractional loads are composited to estimate total loads.

There is no metric to define EMCs for floatables. Floatables will be addressed qualitatively. If floatable impacts are found to warrant detailed characterization, the issue will be addressed during program implementation.

The models represent three hydraulically independent systems and will individually characterize each sewer system. However, the CSO discharge flows and loads at each CSO outfall within each model will be synoptically integrated to calculate receiving water loads. Changes in these flows can be predicted with each model for various alternatives.

The models provide well-developed simulation tools to represent source controls, in-system controls, and BMP alternatives and assess their potential benefits. These and other CSO control strategies will be examined in alternatives analyses that will evaluate CSO reduction under various proposed system configurations.

Section 6

Meetings and Deliverables

The modeling task management team will work with NYS DE C in developing the LTCP to facilitate communication during the project and to maximize the potential for regulatory acceptance. Four meetings will be held with NYS DEC and other interested regulatory agencies to review the deliverables prepared under this task.

The Team will prepare and submit memoranda to the Technical Advisory Committee and NYS DEC at the following stages of the model development:

- Model development
- Data review and model calibration
- Combined sewer system characterization (baseline conditions)

Each memorandum will be discussed with NYS DEC to help the project move forward without controversy. The memoranda will be designed for incorporation into the LTCP report.

6.1 Model Calibration Memorandum

The model calibration and validation memorandum will document model calibration results and conclusions. This document will include:

- Steps taken to calibrated models and final calibration parameters.
- Calibration plots (flow rate and depth) with model prediction and flow monitoring results graphed on the same chart for each meter location and selected calibration events to compare the model performance.
- Model results will be compared to key system performance criteria (e.g. overflow records, street flooding, customer complaints, etc.) and anecdotal information to assess model performance.

The memorandum will document the Modeling Team's assessment of the suitability of the models for use in subsequent evaluations and will be presented to NYS DEC during the model calibration meeting currently scheduled for February 2009.

New York State Department of Environmental Conservation
Division of Water
Bureau of Water Permits, 4th Floor
625 Broadway, Albany, New York 12233-3505
Phone: (518) 402-8111 • **FAX:** (518) 402-9029
Website: www.dec.state.ny.us

VIA E-MAIL AND REGULAR MAIL

September 27, 2007

Rocco Ferraro
Executive Director
Capital District Regional Planning Commission
Park Place
Albany, New York 12205

Re: Albany Pool Combined Sewer Overflow Long-Term Control Plan Development; Combined Sewer System Modeling Work Plan for the Cities of Albany, Rensselaer, Troy, Watervliet, and Cohoes, and the Village of Green Island. SPDES numbers: NY0025747, NY0026026, NY0099309, NY0030899, NY0031046, and NY0033031, respectively.

Dear Mr. Ferraro;

The Department has reviewed the *Combined Sewer System Modeling Work Plan*, September 2007 (CSS Modeling Plan) submitted on August 31,2007. The CSS Modeling Plan is hereby approved.

The CSS Modeling Plan was submitted in accordance with the Department's March 16, 2007 letter approving the *Scope of Work and Combined Sewer System Monitoring and Modeling Plan*, February 2007 contingent upon receipt of 3 detailed reports. The CSS Modeling Plan is the first of the three required reports.

The Department looks forward to receiving the next detailed report on receiving water conditions assessment, due on October 1, 2007. As always, please feel free to call me, at (518) 402-8115, or Andrea Dzierwa, at (518) 357-2377, if you have any questions or concerns.

Sincerely,

Cheryle Webber

Cheryle Webber, P.E.
Environmental Engineer 2