Environmental
Protection

New York City's Operations Support Tool (OST) Executive Summary October 8, 2010

EXECUTIVE SUMMARY

1. Operations Support Tool Background

New York City's Department of Environmental Protection ("City") is developing a state-of-the-art decision support system to support operations and planning throughout the water supply system. The Operations Support Tool (OST) is a forecast-driven simulation and analysis tool that will provide City operators and managers with probabilistic predictions of future system status based on simulation scenarios. The purpose of this paper is to describe OST and discuss the potential that it offers for supporting and enhancing the current releases program from Cannonsville, Pepacton and Neversink Reservoirs of the Delaware River Basin.

2. New York City Water Supply System

New York City's reservoir system is among the most complex water supply systems in the world and comprises the Delaware, Catskill, and Croton Systems. It was built by the City to meet the water supply needs of more than 9 million residents of the City and the surrounding communities. The City professionally manages the system to balance water supply reliability, water quality, environmental objectives, and minimizes water supply costs.

This already complex water supply system faces additional challenges in the future due to aging infrastructure, a projected increase in system demand over the next few decades, potential climate change induced impacts on water quantity and quality, and an evolving regulatory environment. The City is taking a proactive approach to meeting these varied challenges in developing OST, an innovative, real-time decision support system that will assist the City in making short-term and long-term water and demand management decisions using real-time data and forecasted future reservoir inflows. It is a robust state-of-the-art analytical tool to guide the City system operations, evaluate alternative operational strategies, and document diversion and release decisions. It presents an opportunity for the 1954 U. S. Supreme Court Decree Parties (Decree Parties) to evaluate and implement alternative releases programs to effectively manage the Delaware River Basin for enhanced habitat protection, flood mitigation and other environmental concerns while accounting for uncertainty in future hydrological conditions.

2.1. Water Supply Reliability

Ensuring overall water supply system reliability is a key management responsibility and it is critical that the City consistently operate the system in a proactive manner such that it is prepared for unplanned events, such as droughts or infrastructure outages, which could impair its ability to deliver high quality drinking water. It is important to note that the system is not managed in a way that would result in emptying all reservoirs at the worst point in the drought of record. Although this type of operation is assumed in determining the "safe yield" (defined in this White Paper, Section 1.1.3.1) of the system, it is unworkable in actual practice. The consequences of emptying all reservoirs would be catastrophic, and in actual operations, there is no assurance that the historical drought ending rainfall will come to "save the day." Operators need to take action to reduce demands and/or find auxiliary supplies to provide reserves well in advance of reaching extreme drawdown conditions. OST will provide an analytical tool for supporting operation of the New York City water supply to maximize reliability and strengthen the City's ability to make objective, risk-based decisions. It will allow operators and managers to compare different sets of operating rules and evaluate the predicted impacts on water supply reliability criteria quickly and efficiently so that they can make appropriate short-term and long-term decisions. It will also provide a means to document the rationale for those decisions.

2.2. Water Quality Reliability

The City must maintain a safe, high quality water supply for consumers. The system must be ready to respond to a water quality event when it occurs (e.g. turbidity events, chemical spills in or near a reservoir, or an increase in concentrations of disinfection by-product (DBP) precursors, which are naturally organic matter compounds that can react with chlorine to produce DBPs). An integral part of maintaining water quality reliability includes management of the reservoir system such that quality of delivered water is maximized. In the event that contaminants in delivered water could rise to unacceptable levels, appropriate physical and/or chemical treatment must be undertaken. OST will integrate water quality monitoring data on a near real time basis to facilitate decision-making by the City's operations staff.

2.3. Environmental and Other Objectives

In addition to providing a reliable supply of high quality drinking water to its water supply users, the City's operating rules serve to protect downstream users as well as fish habitat and stream ecosystems. Per New York State Conservation Regulations, conservation releases are made to maintain minimum downstream flows in the tailwaters below the City's reservoirs. In addition, releases are also made to maintain flow targets in the Delaware River at Montague and Trenton in accordance with the existing agreements.

Other objectives of Decree Parties include flood mitigation and support for recreation. OST will allow operators to support these objectives by providing assurance that the actions taken will not impact the ability of the City to reliably deliver high quality drinking water. There is great potential for use of OST to support decisions to make releases that provide additional benefits to downstream communities and the Delaware River, over and above the City's obligations. With increased knowledge of water supply system operations and probability of the future inflows coupled with the analytical power of OST, there would be substantial benefits for both New York City and all downstream water users.

3. Operations Support Tool

OST is an analytical tool designed to help guide operating decisions. It simulates and evaluates operating alternatives using forecasted and near real time system information. A given OST simulation is comprised of operating rules and scenario assumptions (e.g. which facilities are currently in or out of service). Most often, the rules and assumptions used will reflect the City's current operating policies and current or planned system conditions. The model input that reflects current policies and conditions will be stored and immediately available for analysis. However, OST itself is not bound to a specific set of rules or assumptions. Rather, it is a platform for developing and testing a variety of operating policies that will provide feedback to operators as to the impacts of particular policies on system performance.

OST is being designed to allow and encourage managers and operators to test the implications of modifying existing rules and system assumptions. OST does not control how operators/managers proceed, but rather it provides data based on realistic simulations that can help guide development of successful operating policies/decisions necessary to achieve short-term and/or long-term objectives. Standard performance criteria for a given simulation are automatically generated by OST, and the user can create additional performance criteria and displays as desired. OST will provide the City's operations staff with the analytical guidance necessary to operate the complex New York City reservoir system and strike a balance between multiple objectives including water supply reliability, water quality goals, environmental concerns, downstream objectives, and treatment/ pumping costs.

OST, built upon the New York City water quality and quantity models, as well as the OASIS model for the Delaware River Basin, is a robust tool that accounts for lower Delaware Basin needs and New York City operational requirements. The City's approach to the use of system models to guide management decisions has proceeded in a step-wise manner, with each step adding complexity and providing overall improvements. OST will continue this step-wise approach, with intermediate upgraded functionality along the way to final deployment of OST.

The conversion from the existing desktop analytical tool to a near-real time and forecast data-driven operations support system serving multiple users represents a fundamental shift in the tool's overall functionality. As such, this project is much more than a set of incremental enhancements to the current water quality and quantity models, and is rather a complete overhaul to effectively convert the tool to its new purpose. Major modifications include (Figure 1):

- Providing connectivity with a large array of near real-time system operations, water quality, and environmental data;
- Developing and incorporating near real-time National Weather Service and statistical ensemble inflow forecasts;
- Designing a completely new interface to make the tool accessible to multiple City user groups with diverse needs and technical skills;

- Improving model post-processing capabilities for easier and more powerful data analysis and presentation; and
- Developing a database to store and manage multiple data sets from multiple users, and deploying OST across the City's network.

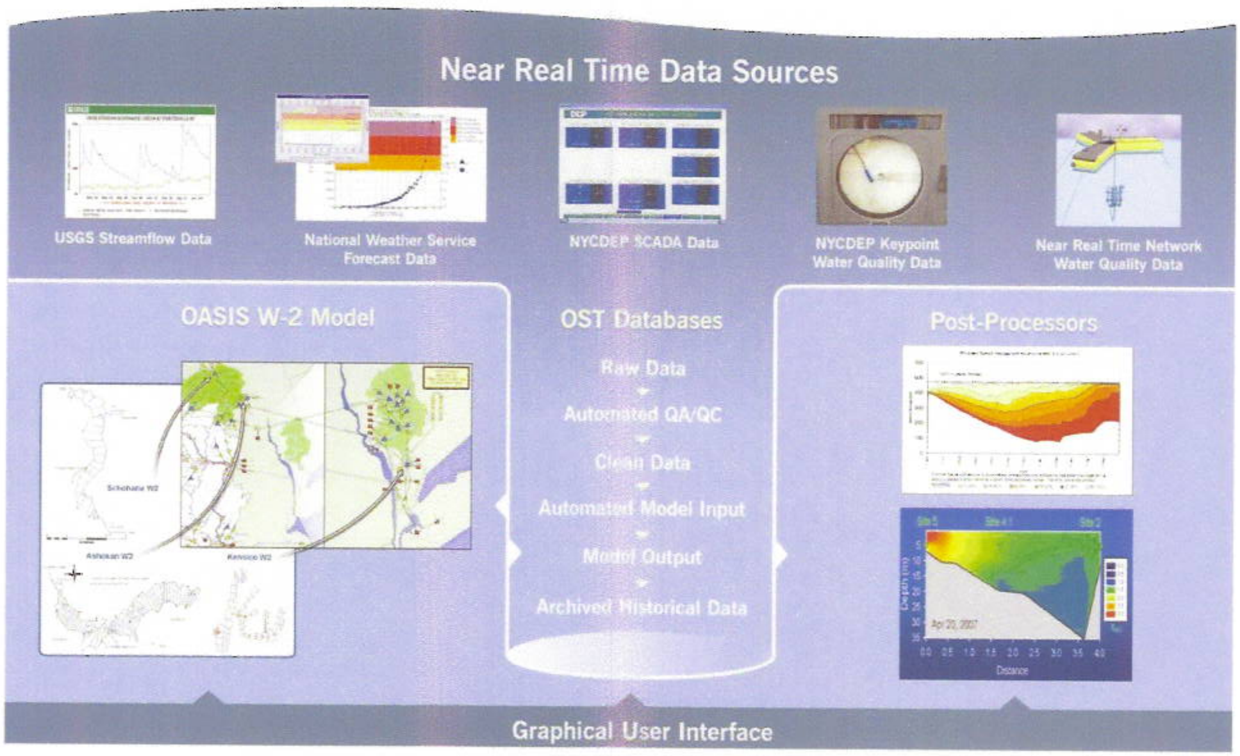

Figure 1: Major OST Components

4. Use of Forecasts in OST

Probabilistic streamflow (reservoir inflow) forecasts are critical in helping to quantify water supply quantity and quality risks. In addition, streamflow forecasts will aid water managers in developing robust long-term operating rules for the New York City system. There are essentially two types of forecasts that will be included in OST: (1) forecasts based solely on historical streamflow observations and (2) forecasts based on a combination of historical information, estimates of current meteorologic, hydrologic and climatic conditions, and meteorological forecast information. In OST, forecasts will be used to inform real-time day-to-day operating decisions and to evaluate the near-term (up to a year) expected benefits of alternative operating rules and policies.

Using probabilistic inflow forecasts allows managers to assess the risks and uncertainties associated with operating decisions. When making real-time operating decisions, water managers will use OST in Position Analysis (PA) mode. PA involves multiple simulations of potential operations over a future period (several weeks to a year). Each simulation starts with the system at its current state (current reservoir elevations, current water quality, etc.), but uses a different projection of future inflows and other important system drivers.

5. Operations Support Tool Usage

OST makes use of real-time system information (e.g. reservoir levels, streamflows) and forecasts (e.g. streamflows, meteorological drivers) to provide the City with objective, data-based decision support that will improve system operations including operation of the Delaware Reservoirs and potentially in improving the Delaware release program.

The following sections describe how OST will be used with respect to the overall system and in the context of the Delaware release program.

5.1. OST Usage - General

There are two operating modes for OST, Position Analysis (PA) and Simulation (Sim) modes. PA mode generally is intended to support near-real time operations decision-making. PA simulations begin with today's date and look forward (days, months) using the forecasted inflow and meteorological drivers. All members of the forecast ensemble begin from the same set of initial system conditions, which would include today's reservoir storage levels, streamflows, etc. Typically, these PA simulations might include a "baseline" operations scenario and several sets of alternate operating rules. The impact of these alternate operations can then be evaluated based on the performance measures chosen to meet the objectives.

In contrast, rather than running an ensemble of forecasts for a short period of time (i.e. less than one year), Sim mode consists of a single long-term (e.g. 80 years of historical hydrology for the New York City OST) simulation. This allows for evaluation of operating rules or infrastructure changes over a long-term basis and will typically be used for development/testing of long-term operating rules and for capital planning. In addition, Sim mode could be used to evaluate the sensitivity of system parameters to long-term hydrologic changes (e.g. climate change scenarios).

5.2. OST Usage in the context of the Delaware River Basin

OST is a robust platform for real-time operations that accounts for multiple objectives and system complexity in a way that static analyses (e.g. safe yield and table-based approaches) cannot. OST therefore is a platform that is well-suited for developing and testing release rules for the Delaware Reservoirs. OST could be used to provide near term support of the FFMP program and ultimately, in association with a commitment to provide long term sustainable source(s) of water by the other Decree Party members could form the basis for an enhanced future release program.

5.3. OST in Support of the FFMP Agreement

OST can initially support releases under the current FFMP program by providing an analytical tool to evaluate the volume of water available for release. Since OST includes operating rules for the entire New York City System, it necessarily accounts for water quality and other objectives throughout the system, providing a more realistic accounting of water and protecting water supply reliability objectives, such as ensuring refill prior to the start of the drawdown season.

Since OST relies on an ensemble of forecasts of possible future inflows, this approach would represent a risk-based approach, in which the risks of not meeting water supply and water quality objectives can be quantified. A risk-based approach would protect the City's water supply users while helping to define a forecast-based excess release quantity of additional water from unallocated Delaware Basin storage that can be made available to meet Delaware Basin release objectives. In more general terms, better system-wide operation with OST will protect the New York City supply and provide benefits for the Decree Parties.

OST would further enable the Decree Parties, in cooperation with the City, to develop enhanced FFMP programs (similar to the releases program suggested by Fisheries staff of the New York State Department of Environmental Conservation (NYS DEC) and the Pennsylvania Fish and Boat Commission (PFBC)). OST enables sensitivity testing of alternative operating rules to variable system parameters (e.g. demand, infrastructure, etc). Better system-wide operations with OST will protect New York City and provide opportunities for improved fisheries habitat protection and enhanced flood mitigation.

5.4. OST Use for Modified Release Plan

The NYS DEC and PFBC Joint Fisheries White Paper (JFWP), submitted to the Decree Parties, calls for large reservoir releases, particularly from Neversink Reservoir. The proposal also results in increased drought days, based on 35 mgd currently available for releases from the unused portion of the New York City diversion allocation of 800 mgd and violates the drought neutral criterion prescribed by the Decree Parties. Tangible examples, for illustrative purposes, of enhanced releases with forecast-based excess release quantities of 100 mgd, 75 mgd, or 50 mgd available are presented below. Adjustments in releases may be needed to ensure that the drought day criterion, prescribed by the Decree Parties, is not violated with these tables. The tables presented supplement the four schedules of releases, with 35 mgd, 20 mgd, 10 mgd or 0 mgd, in the current FFMP.

Table 4-1:

FFMP Table 3 Supplement (with 100 mgd Available) compared to Current FFMP Table 3 (with 35 mgd Available); Modified NYS DEC / PA FBC Fisheries Proposal

	Winter		Spring		Summer			Fall		
Cannonsville Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	1500/1500	1500/1500	*	*	*	1500/1500	1500/1500	1500/1500	1500/1500	1500/1500
L1-b	250/250	*	*	*	*	*	525/350	400/300	300/275	250/250
L1-c	150/110	400/110	400/200	400/250	500/275	525/275	525/275	400/275	300/140	150/110
L2-High	135/80	325/80	325/190	350/240	400/260	425/260	425/260	350/260	250/115	135/80
L2-Low	115/80	300/80	300/190	325/240	400/260	400/260	400/260	325/260	250/115	125/80
L3	100/70	125/70	150/100	175/100	200/175	200/175	200/175	150/95	125/95	100/70
L4	55/55	55/55	75/75	75/75	130/130	130/130	130/130	55/55	55/55	60/60
L5	50/50	50/50	50/50	50/50	120/120	120/120	120/120	50/50	50/50	50/50

	Winter		Spring		Summer			Fall		
Pepacton Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	700/700	700/700	*	*	*	700/700	700/700	700/700	700/700	700/700
L1-b	185/185	*	*	*	*	*	250/250	200/200	200/200	185/185
L1-c	125/85	125/85	125/110	125/130	150/150	150/150	150/150	125/150	125/100	125/85
L2	100/65	100/65	100/100	100/125	140/140	140/140	140/140	100/140	100/85	100/60
L3	80/55	80/55	80/80	80/80	100/100	100/100	100/100	80/55	80/55	80/55
L4	45/45	45/45	50/50	50/50	85/85	85/85	85/85	40/40	40/40	40/40
L5	40/40	40/40	40/40	40/40	80/80	80/80	80/80	30/30	30/30	30/30

	Winter		Spring		Summer			Fall		
Neversink Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	190/190	190/190	*	*	*	190/190	190/190	190/190	190/190	190/190
L1-b	110/100	*	*	*	*	*	125/125	125/125	110/85	110/95
L1-c	90/65	90/65	90/85	90/100	125/110	125/110	125/110	90/110	90/75	90/60
L2	75/45	75/45	75/75	90/90	110/100	110/100	110/100	90/100	75/70	75/45
L3	60/40	60/40	60/50	60/50	90/75	90/75	90/75	60/40	60/40	60/40
L4	35/35	35/35	40/40	40/40	60/60	60/60	60/60	30/30	30/30	30/30
L5	30/30	30/30	30/30	30/30	55/55	55/55	55/55	25/25	25/25	25/25

Table 4-2:

FFMP Table 3 Supplement (with 75 mgd Available) compared to Current FFMP Table 3 (with 35 mgd Available);

Modified NYS DEC / PA FBC Fisheries Proposal

	Winter		Spring		Summer			Fall		
Cannonsville Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	1500/1500	1500/1500	*	*	*	1500/1500	1500/1500	1500/1500	1500/1500	1500/1500
L1-b	250/250	*	*	*	*	*	525/350	400/300	300/275	250/250
L1-c	150/110	400/110	400/200	400/250	500/275	525/275	525/275	400/275	300/140	150/110
L2-High	125/80	300/80	300/190	350/240	425/260	425/260	425/260	350/260	275/115	125/80
L2-Low	100/80	250/80	250/190	300/240	350/260	350/260	350/260	300/260	200/115	100/80
L3	75/70	75/70	100/100	100/100	175/175	175/175	175/175	100/95	100/95	75/70
L4	55/55	55/55	75/75	75/75	130/130	130/130	130/130	55/55	55/55	60/60
L5	50/50	50/50	50/50	50/50	120/120	120/120	120/120	50/50	50/50	50/50

	Winter		Spring		Summer			Fall		
Pepacton Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	700/700	700/700	*	*	*	700/700	700/700	700/700	700/700	700/700
L1-b	185/185	*	*	*	*	*	250/250	200/200	200/200	185/185
L1-c	125/85	125/85	125/110	125/130	150/150	150/150	150/150	125/150	125/100	125/85
L2	90/65	90/65	90/100	90/125	140/140	140/140	140/140	90/140	90/85	90/60
L3	80/55	80/55	80/80	80/80	100/100	100/100	100/100	80/55	80/55	80/55
L4	45/45	45/45	50/50	50/50	85/85	85/85	85/85	40/40	40/40	40/40
L5	40/40	40/40	40/40	40/40	80/80	80/80	80/80	30/30	30/30	30/30

	Winter		Spring		Summer			Fall		
Neversink Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	190/190	190/190	*	*	*	190/190	190/190	190/190	190/190	190/190
L1-b	110/100	*	*	*	*	*	125/125	125/125	110/85	110/95
L1-c	90/65	90/65	90/85	90/100	125/110	125/110	125/110	90/110	90/75	90/60
L2	75/45	75/45	75/75	90/90	110/100	110/100	110/100	90/100	75/70	75/45
L3	60/40	60/40	60/50	60/50	90/75	90/75	90/75	60/40	60/40	60/40
L4	35/35	35/35	40/40	40/40	60/60	60/60	60/60	30/30	30/30	30/30
L5	30/30	30/30	30/30	30/30	55/55	55/55	55/55	25/25	25/25	25/25

Table 4-3:

FFMP Table 3 Supplement (with 50 mgd Available) compared to Current FFMP Table 3 (with 35 mgd Available);

Modified NYS DEC / PA FBC Fisheries Proposal

	Winter		Spring		Summer			Fall		
Cannonsville Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	1500/1500	1500/1500	*	*	*	1500/1500	1500/1500	1500/1500	1500/1500	1500/1500
L1-b	250/250	*	*	*	*	*	525/350	400/300	300/275	250/250
L1-c	150/110	300/110	300/200	350/250	425/275	450/275	450/275	350/275	250/140	150/110
L2-High	110/80	200/80	200/190	260/240	350/260	350/260	350/260	300/260	215/115	110/80
L2-Low	90/80	150/80	190/190	250/240	300/260	300/260	300/260	260/260	150/115	90/80
L3	75/70	75/70	100/100	100/100	175/175	175/175	175/175	100/95	100/95	75/70
L4	55/55	55/55	75/75	75/75	130/130	130/130	130/130	55/55	55/55	60/60
L5	50/50	50/50	50/50	50/50	120/120	120/120	120/120	50/50	50/50	50/50

	Winter		Spring		Summer			Fall		
Pepacton Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	700/700	700/700	*	*	*	700/700	700/700	700/700	700/700	700/700
L1-b	185/185	*	*	*	*	*	250/250	200/200	200/200	185/185
L1-c	125/85	125/85	125/110	125/130	150/150	150/150	150/150	125/150	125/100	125/85
L2	80/65	80/65	90/100	100/125	140/140	140/140	140/140	125/140	90/85	80/60
L3	70/55	70/55	80/80	80/80	100/100	100/100	100/100	70/55	70/55	70/55
L4	45/45	45/45	50/50	50/50	85/85	85/85	85/85	40/40	40/40	40/40
L5	40/40	40/40	40/40	40/40	80/80	80/80	80/80	30/30	30/30	30/30

	Winter		Spring		Summer			Fall		
Neversink Storage Zone	1-Dec - 31-Mar	1-Apr - 30-Apr	1-May - 20-May	21-May- 31-May	1-Jun - 15-Jun	16-Jun - 30-Jun	1-Jul - 31-Aug	1-Sep - 15-Sep	16-Sep - 30-Sep	1-Oct - 30-Nov
L1-a	190/190	190/190	*	*	*	190/190	190/190	190/190	190/190	190/190
L1-b	110/100	*	*	*	*	*	125/125	125/125	110/85	110/95
L1-c	90/65	90/65	90/85	90/100	125/110	125/110	125/110	90/110	90/75	90/60
L2	60/45	60/45	75/75	90/90	110/100	110/100	110/100	90/100	75/70	60/45
L3	50/40	50/40	60/50	60/50	85/75	85/75	85/75	50/40	50/40	50/40
L4	35/35	35/35	40/40	40/40	60/60	60/60	60/60	30/30	30/30	30/30
L5	30/30	30/30	30/30	30/30	55/55	55/55	55/55	25/25	25/25	25/25