DELTA DRAINAGE AND IRRIGATION SYSTEM
Complex Multifunction Hydraulic System Analysis
by Gabor M. Vasarhelyi, P.Eng., P.E., of GMV Engineering

Background

Delta, British Columbia is located in the Fraser River delta on the shores of the Pacific Ocean, just south of the City of Vancouver. Delta comprises mostly agricultural land, with typical ground elevations near sea level. Levees protect the area from potential floods from the Fraser River and tidal surges from the Pacific Ocean.

Of the 13,500 hectares (ha) watershed, 6,300 ha is active agricultural land, 3,500 ha is the environmentally sensitive Burns Bog, and the rest is a mix of urban and industrial developments and transportation corridors.

The Delta hydraulic system includes some 900 kilometres (km) of ditches, 20 outfalls, 1,700 culverts and bridges, and over 100 water-level and flow-control structures. The system operates in Drainage mode from fall to spring, providing drainage and flood protection for the area, and in Irrigation mode from spring to fall, providing agricultural water supply. Primary concerns related to the system include: flooding of low-lying areas, the quantity and quality (salinity) of the agricultural water supply, and water retention in Burns Bog.

A major highway project (South Fraser Perimeter Road [SFPR]) is being constructed through the low lands of Delta and impacts the existing drainage and irrigation system. Figure 1 provides an overview of the Delta Drainage and Irrigation System.

Figure 1
Overview of the Delta Drainage and Irrigation System
Objectives

The objectives of this hydraulic analysis include:

- Support the design and implementation of an SFPR drainage system that provides only beneficial impacts to the existing Corporation of Delta drainage and irrigation system
- Enhance the irrigation system by a four-fold increase in supply capacity, allowing only high-quality (low-salinity) water to enter the system
- Improve water retention and management for Burns Bog

In Drainage mode, the primary measurement of the system’s hydraulic performance is the maximum water surface elevation during critical storm events. The performance objective is to achieve lower maximum water surface elevations anywhere in the impacted watershed (upstream or downstream of the SFPR project) than would occur during the same storm events in the existing system.

For Irrigation mode, the objectives are to: 1) deliver increased demand to anywhere in the system within a predefined range of water surface elevations, and 2) ensure that flooding will not occur during summer storm events when the channel system is filled with irrigation water.

The objectives for Burns Bog are to: 1) limit winter flood elevations to prevent external flow into the Bog, and 2) optimize water retention during the transitional period (late winter to early summer) to maximize wetting of the Bog during the dry summer period.

The Concept

To achieve the project’s multiple objectives, the key elements of the system concept include: drainage capacity improvements between the SFPR project and the system outfalls to the Fraser River; the introduction of pump stations with upstream water-level controls; and the introduction of a series of automated water-level control gates to maximize system storage and optimize the delivery of water in the system.

The improved system will also include a series of water-level and flow-monitoring devices to observe system performance and assist in operation management and the refinement of system controls.

Approach

The approach selected for the evaluation of the system included: establishing baseline (pre-project) hydraulic parameters for both Drainage and Irrigation mode operations; assessing potential project impacts without improvements to the hydraulic system; evaluating a variety of
improvement options; selecting system improvements; and evaluating system performance with the selected improvements in place.

**System Analysis**

**xpswmm** by XP Software was selected as an evaluation tool for the hydrologic and hydraulic analysis of the system because of its ability to simulate a variety of hydrology events, boundary conditions, hydraulic structures, and passive and active hydraulic controls. The ability to use Real Time Controls (RTC) for the simulation of automated water-level controls was particularly important for this project. The available two-dimensional (2D) module will have future use in the project in areas where more precise definition of the flood plain is required.

Data used for system definition included: available records, high-definition (10-centimetre [cm] pixels) ortho photography, aerial surveys and Light Detection and Ranging (LIDAR) data for surface topography, field surveys for below-water topography and hydraulic structures, soils data, and land-use data. All system data was compiled in Geographic Information System (GIS) feature sets, processed and used in the hydrologic and hydraulic models.

**xpswmm** models were developed for pre-project, and for the project development scenarios with and without improvements in place.

Drainage mode models included hydrology and boundary conditions that are typical for the season, and the hydraulic system with controls (pump stations, weirs, and control gates) set appropriately for Drainage mode operations. Hydrology scenarios included a series of synthetic storm events and an observed critical event that caused extensive flooding in the area.

Irrigation mode models included the same hydraulic system with control settings appropriate for the season, and water-use distributed throughout the system.

Pre-project **xpswmm** models were used to establish pre-project water surface elevations and water delivery capacities, and to identify existing system deficiencies. Since the primary interest of the analysis is water surface elevations, not the precise mapping of floodplain boundaries, a simplified, quasi-2D approach was used for floodplain analysis, where floodplain storage was assigned to a grid of storage nodes.

Post-project **xpswmm** models were used to identify potential project impacts, evaluate improvement options, select improvements, and confirm system performance with the selected improvements. These models incorporated the drainage and irrigation channel improvements, a reversible drainage discharge and irrigation intake pump station with salinity controls, 2 irrigation lift stations, 4 automated water-level control gates, and several minor semi-automatic or manual control structures.
Key control features for irrigation mode operation were pump stations with remote, upstream water level controls and automated water level control gates with either upstream or downstream water level controls, or controls when the sensors are installed at a remote location. The primary intake pump station is equipped with salinity sensors to prevent the intake of river water when the quality of water is not suitable for irrigation.

Figure 2 shows an example of a lift station setup with upstream water level controls at a remote location using the Special Pump (Pump5) routine of xpswmm.

**Figure 2**

*Pump Control Setup Using the Special Pump (Pump 5) Routine*

In this example Pump 3 of a 3-pump station setup starts to operate when the depth at Node NIC09999 is less than 1.10 m and stops when the depth exceeds 1.15 m.
Water surface elevation controls in the main irrigation channels are provided by moveable weirs such as overshot gates shown on the photo in Figure 3 and the diagram on Figure 4.

**Figure 3**
*Overshot Gate (Source: INSTREAM Water Control Projects Ltd. Web site)*

![Overshot Gate](image1)

*Figure 4*
*Overshot Gate Typical Design (Source: armtec Overshot Gate Brochure)*

![Overshot Gate Diagram](image2)

These gates, or moveable weirs release water according to water surface elevations at selected location of the system. The operation of these gates are simulated using the Real Time Control (RTC) module of xpswmm with the Variable Diameter Conduit option for simulating the operation of these structures. Figure 5 is an example for simulating the moveable weir with a variable diameter conduit.
In this example the RTC setup of the North Control Gate is demonstrated. The gate releases water when the water level at Node NIC1500, which is the intake node of the pump station in the previous example, falls below -0.50 m. The control node is located about 3.5 km away from the control gate.

**Challenges**

In the existing system, water levels are measured at most of the outfalls with some frequency. Flow is approximated at pump stations by recording the time of operation of the pumps. Only anecdotal data was available regarding the performance of the internal system. The lack of sufficient performance data created particular challenges in the calibration of the pre-project model and required building sufficient flexibility in the design of improvements to allow for future operational adjustments, as necessary.

**Benefits**

Stakeholders’ perceptions of system performance, the reasons for flooding, practical water demand, and deficiencies in delivering irrigation water, as well as water retention issues in Burns Bog, are largely based on visual observations of the performance of individual system elements. The comprehensive xpswmm model, incorporating all major functions of the complex hydraulic system, assisted in confirming or modifying perceptions, clarifying performance
demands, and determining improvement needs to satisfy project objectives with the best use of available resources.

Previously only isolated areas of the Delta drainage and irrigation system were evaluated using simple engineering calculations or limited hydrologic and hydraulic modeling due to the perceived high cost of modeling. This process proved that while system evaluations using comprehensive system modeling requires considerable resources to complete, the benefits of the process in decision support and overall project cost outweigh the cost of the evaluation process.

**Results**

The result of this system design assisted by the hydrologic and hydraulic analyses using the xpswmm model, resulted in an efficient drainage and irrigation system that prevents flooding during the irrigation season, provides high quality (low salinity) irrigation water in quantities that are four times greater than the supply capacity of the existing system within tightly controlled water surface elevation limits to supply irrigation water to agricultural lands but prevent the flooding of low lying areas at the same time. Figure 6 shows the profile of one of the main irrigation channels that include the primary intake pump station, an automated water level control gate and an internal lift station.

**Figure 6**
*Profile of the North Irrigation Channel - Irrigation Mode Operation*
Figure 7 shows the maximum water surface elevations at the Alexander Outfall before and after the implementation of the SFPR project. The chart indicates that the project related drainage improvements will result in more than 0.5 m reduction in maximum water surface elevations in an industrial area.

**Figure 7**

*Maximum Water Surface Elevations at Alexander Outfall - Drainage Mode Operation*

The project is currently (Fall 2010) under construction. Project implementation includes: a monitoring program with flow- and water-level measurements at all new major and several existing control structures to verify improved performance evaluation, the refinement of system controls, and continued support for future system improvements. The **xpswmm** model developed for the design of the system will become an operation management tool after the implementation of the project.

*For more information, contact Gabor M. Vasarhelyi, P.Eng., P.E., of GMV Engineering, at 778-837-0965 or gabormv@gmveng.ca*