

Getting piping design right with hydraulic analysis

The city of Surrey, B.C., used hydraulic analysis to meet the challenges of designing a multiphase district energy project.

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Courtesy city of Surrey, B.C.

Aerial view of the Surrey, B.C., City Centre.

The distribution piping network is an integral part of any district energy system. Even though distribution piping design and construction account for 30 percent to 50 percent of the total district energy system cost, those phases take most of the effort and cause most of the disruption during the project compared to its other components.

For that reason, most experienced district energy system owners will invest in the design stage to get it right the first time. Hydraulic analysis is a crucial component of the distribution piping design process and can provide high value in reduced capital costs and maximized overall system performance. Engineers face many challenges and considerations in conducting hydraulic analyses. However, as the city of Surrey, B.C., Canada, illustrates, hydraulic analysis can provide critical guidance in the design and early construction of large, city-scale district energy systems.

A BALANCING ACT

Hydraulic analysis is an art in itself, combining simple pressure loss concepts with an experienced engineer's intuition. The engineer must balance initial capital

cost, operating cost, system reliability and uncertainties around future development, among other challenges specific to the system. For example, larger pipes will mitigate some of the risks associated with the uncertainties of future development and will reduce the pumping costs, but they come at a higher initial capital investment and more disruption during construction. Engineers must consider that pipe size is governed by maximum velocities and pressure gradients, which also influence material choices. Classically, the maximum speed in the piping should not exceed 2.4 m/sec (8 ft/sec) especially for pipe material that has lining (like fiberglass-reinforced plastic and high-density polyethylene). It is also advisable not to exceed the 200-250 Pa/m (2-2.5 ft/100 ft) pressure gradient.

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Another factor engineers must consider is load diversification – the assumption that all connected loads will

not require heat transfer at the same time; therefore the system peak will be lower than the sum of all individual building peaks. Depending on the characteristics of all connected loads, the load diversity may range between 0.7 and 0.95.

CASE STUDY: SURREY, B.C., DISTRICT ENERGY SYSTEM

In recent years, the city of Surrey in beautiful British Columbia has used hydraulic analysis in the design of a new, multiphase district energy project. The city is the fastest-growing community in the Metro Vancouver region (regional population more than 2.4 million and growing). Surrey's City Centre, located roughly at the geographical center of Metro Vancouver, has a high level of connectivity due to its proximity to the Fraser River, the Trans-Canada Highway and Vancouver's fastest transit system, the SkyTrain. As part of Metro Vancouver's growth strategy, Surrey is slated to become the region's second center of commerce and will provide economic opportunities for the rapidly growing area. Illustrating Surrey's fast growth, there are approximately 10,000 new residents in the city every year, and the population (now more than 500,000) is projected to surpass that of the city of

Vancouver within the next 15 to 20 years. The progress of Surrey's City Centre over the coming decades will be characterized by high-density, transit-oriented development with a mix of residential and commercial floor space.

The long-term vision for Surrey's sustainable growth includes an integrated hot water district energy network (standard operating range 70-95 degrees C [158-203 F]) covering the entire City Centre area. At full buildout, this will include multiple energy centers with a range of different heating sources. Natural gas will serve the network as a startup fuel as well as a source of peaking power and redundancy in the future. Various phases of low-carbon renewable energy development are planned for in the utility's 30-year capital plan, including geothermal, biomass from local clean wood waste, sewer heat recovery and biogas generated from the city's curbside organic waste collection.

The city is planning a system that, phased over 30 years, may ultimately include up to five energy centers connected to three main nodes. These five plants would total over 120 MW of thermal load (410 MMBtu/hr) supplied to more than approximately 2.3 million sq m (25 million sq ft) of space via more than 20 km (12.4 miles) of trench distribution piping with hundreds of end-user connections. This distribution system needs to be

installed alongside existing utility corridors and future infrastructure, as well as coordinated with ongoing constructions and traffic constraints.

By late 2016, two phases of the project were completed, with two temporary gas-fired energy centers connected to six buildings totaling more than 139,000 sq m (1.5 million sq ft) via 1,100 m (3,609 ft) of distribution piping. One of those temporary energy centers, at West Village Park, will be replaced by a permanent plant (fig. 1) in 2018. There is also a third, isolated district energy node supplying hot water heating and cooling to the City Hall. This geothermal-based system will be connected to the Surrey district energy network by the end of this year. (To learn more about this system, see "Opportunity Seized: Fast-growing Surrey, B.C., embraces district heating" in Third Quarter 2014 *District Energy*.)

The city of Surrey serves as a great case study to both illustrate a hydraulic analysis involved in implementing a district energy system and to demonstrate such an analysis's true value. Appreciating the challenge of building a huge district energy system over many years, the city saw the value of completing a hydraulic analysis at the early stages of its district energy scheme. Even though the hydraulic analysis design process is highly iterative in nature, it helped the city understand the implication of different design ap-

proaches. It allowed city officials to make timely decisions regarding the main district energy system parameters such as the main header pipe sizes, pump selection, expansion tank selection and pressure requirements (that lead to the right piping material). The process also flagged some design challenges like static pressure due to change in elevation and other issues related to having multiple energy centers feeding into the same distribution piping system.

PHASING AND SCENARIO DEVELOPMENT

As demonstrated by Surrey's district energy project, the first step in conducting a meaningful analysis is understanding the district energy system and working within its constraints. Completing a full buildout scenario is usually the most straight-forward approach. This captures the maximum potential size of the system by including all future developments at their full peak load. It provides a general indication of the minimum requirements of the distribution piping system backbone.

However, completion of a near-term scenario may also be needed. For example, where a full buildout scenario for a distribution network fed from multiple plants might require the smallest pipe header size, a near-term analysis may show that a larger header pipe is needed when an area is still fed from a single

FIGURE 1. Rendering of Surrey's West Village Energy Centre, a permanent facility expected to open in 2018.



Source: Francl Architecture.



Surrey's new LEED Gold-certified City Hall is currently served by an isolated district energy node utilizing thermal energy from a 400-bore geothermal field beneath the building and adjacent public plaza. By the end of 2017, this system will be connected to the broader Surrey district energy system network.

plant. Thus, both near- and long-term scenarios may be critical for district energy system planners to consider.

Such was the case for the city of Surrey, with its plan to build a multiplant network over 30 years. One of the challenges the city faced was to develop a phased approach that accommodated the long-term customer growth projections without losing sight of initial capital spending. The city followed a systematic approach to project the scale and distribution of system load in the first 15 years, which led to a second, near-term scenario that was used to determine the pipe sizing required to meet the system demand with only one energy center in operation.

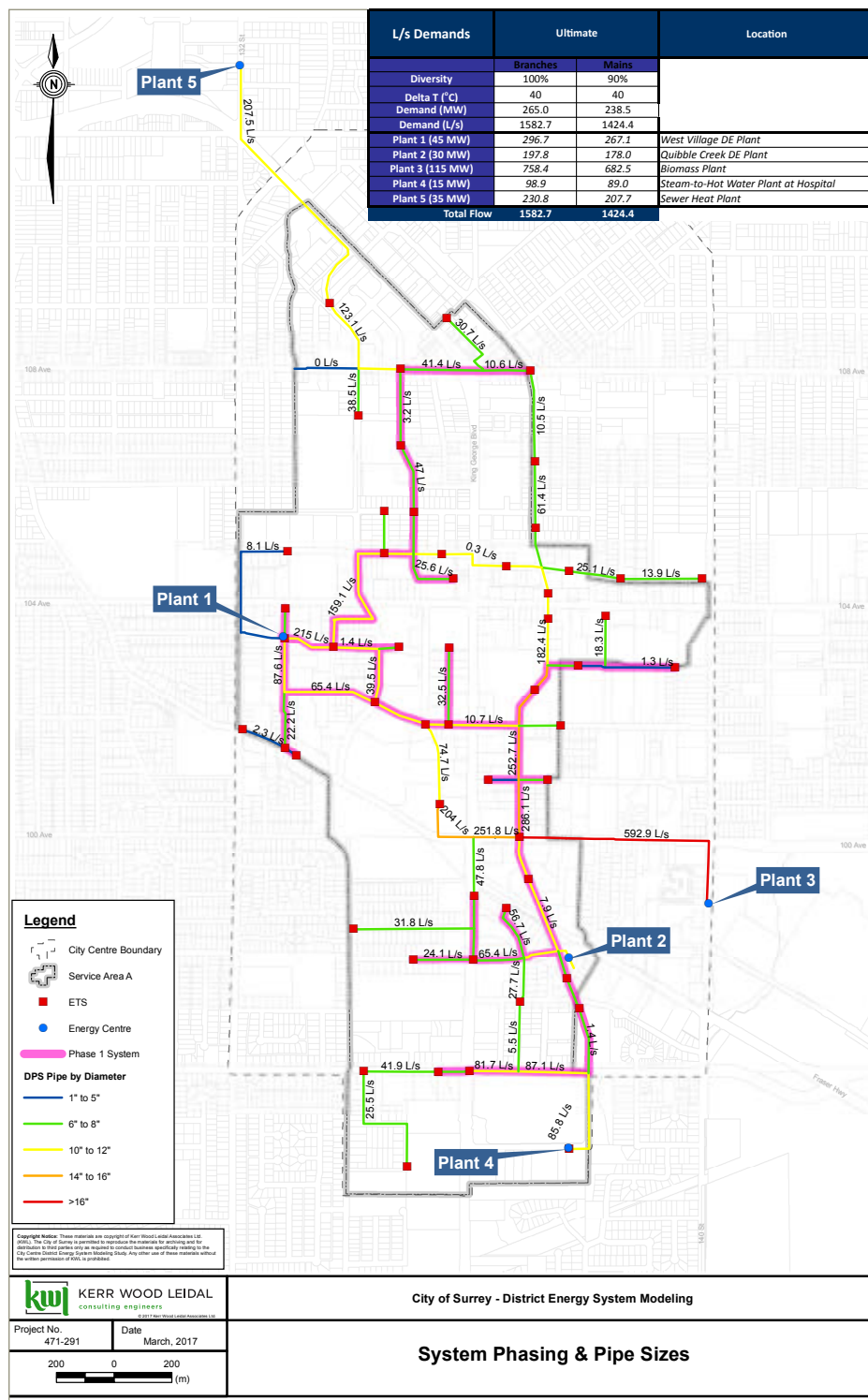
By understanding the minimum pipe diameters required in each of the two scenarios described above, the city was able to adopt a “looped” approach to meet the long-term system load while limiting the initial pipe diameters to what would be required in the first 15 years. This was accomplished by relying on future loops in the pipe network to meet system demands in the long term as well as increasing the pipe sizes in strategic sections.

A third hydraulic analysis scenario was also developed for Surrey so the city could better understand the system constraints when the ultimate objective is met of having multiple heat source inputs including low-carbon renewable technologies. (Figure 2 shows final pipe sizing selected for the Surrey district energy project following the city’s analysis of all three scenarios.)

INTEGRATION OF GIS

To many, the classic approach to hydraulic analysis briefly discussed above is familiar and is what is usually implemented. However, the Surrey project team took hydraulic analysis to the next level, incorporating geographic information system (GIS) data. The city has advanced GIS capabilities, which allowed it to share with the design team very useful information such as the square footage, architectural type and locations of the projected loads – all of which assisted in building an accurate representation of the distribution piping system. Further,

FIGURE 2. Final sizing of district energy distribution piping system, Surrey, B.C.

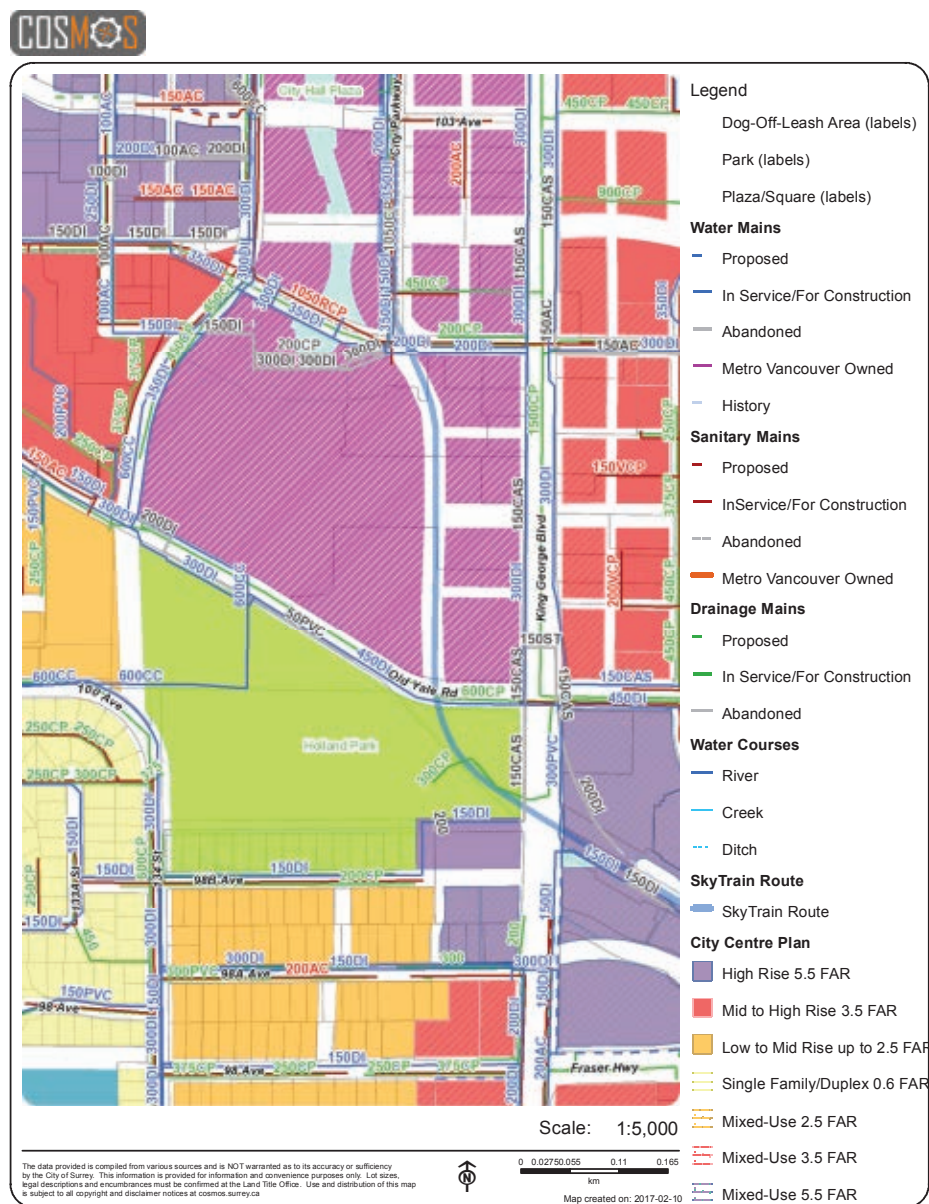


Source: Kerr Wood Leidal Associates.

extensive GIS data provided information such as the location of existing and future utilities, traffic constraints, future transit routing, etc. (See a screenshot of Surrey’s COSMOS geographic information system in figure 3.)

Having a link between the hydraulic analysis software and GIS allowed the design team to develop a valuable, robust design and to communicate information easily. The district energy utility employees were capable of forecasting future

FIGURE 3. Screenshot of the city of Surrey's web-based COSMOS geographic information system. Available GIS data provided by the city assisted engineers in selecting piping routes to avoid arterial streets or those with many buried services.



Source: City of Surrey, B.C.

loads at a parcel level, on a year-to-year basis, by layering on detailed projections of development over time. Additionally, GIS was used to identify the optimal pipe routes based on the roads that will have the greatest density of heating demands, while avoiding those roads that are congested with other utilities or have traffic challenges. Considering these at the conceptual design phase facilitates constructability and reduces cost in the long term.

Once the piping system modeling was completed, sets of figures were generated with visually appealing color grades to show pipe sizes, pressure gradients and phasing. These figures allowed seamless communication between the design team and the different departments within the city. In other words, the hydraulic analysis linked to GIS facilitated both the design process and the planning process. The city will also be able to update the model/GIS moving forward to

continue with optimizing the distribution piping system as the city develops.

GETTING IT RIGHT

Overall, the hydraulic analysis process can provide valuable information at an early stage in distribution piping system planning: the right piping design for all phases of the project, the right equipment selection and the right cost for the intended use. In addition, hydraulic analysis can act as an invaluable tool for planning future developments as the system evolves. Engineers can use hydraulic analysis to balance many of the competing priorities in a district energy system; and by complementing the hydraulic analysis design process with GIS software, much more useful information can be brought forward to facilitate the process. It is crucial to keep seamless communication between the owner and the engineer by setting up the ground rules in the early stages of the design and planning processes. This allows the engineer and the client to better understand the system as is, as well as where the client wants the system to be in the future.

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