RISK ANALYSIS IN PLANNING: COMMUNITIES AND WATER EMERGENCIES

Ross T. Newkirk, Ph.D., MCIP, RPP
Director, School of Planning, University of Waterloo

Keywords: Potable water emergency, safe municipal water, protecting ground water

Abstract

Water emergencies are serious matters for municipalities and they are more than simply engineering problems. Health and business can be negatively effected and lives lost. This paper is centered on the broader risk aspects of potable municipal water supply. Selected risks associated with source of supply, bulk transmission, treatment and distribution are identified, and considerations for planners outlined. Planners can help assess risks and can take professional initiatives to manage parts of some of the risks through land use control, jurisdictional arrangements and information development.

Introduction:

There is increasing concern about the adequacy of municipal infrastructure that relates to managing water in communities. Water emergencies result from a variety of reasons and involve potable water, wastewater, storm water and flood considerations. In previous papers the author (Newkirk, 1995, 1996, 1997, 1999b, 2000) has discussed a number of planning issues related to storm water and floods. This paper centers its attention on planning issues related primarily to potable water supply and draws on the author's experience on risk assessment panels for large and small-scale municipal water supply systems. Municipalities are facing significant challenges with their potable water supply systems.

In Canada, one province (British Columbia) has at times had in excess of 100 communities under a "boil water" order at one time. Recently there have been high profile cases where break down of water treatment equipment and break down of procedure has led to significant illness in communities and loss of life. The most notable recent cases in Canada are North Battleford, Saskatchewan, and Walkerton, Ontario; in both cases large numbers of citizens fell seriously ill and in the latter case, a number of deaths occurred. This has resulted in two detailed, lengthy and costly judicial investigations: North Battleford (2001), and Walkerton, (2001).

It is a topic of another paper to delve into the detailed lessons learned through these inquiries. The reader will find extensive information available through the web sites identified in the references as well as a number of related web sites and the final reports. This paper takes a broader view of important considerations related to municipal water supplies and matters to be considered by planners.

Context:

In large part, the development and operation of municipal water systems historically has been seen as primarily an engineering matter. The focus has usually been on ensuring there is a reliable and robust water collection, treatment and distribution system. As a member of some water system risk assessment panels, the author has noted the engineering attention to reliability and safety often differs between large and smaller municipal systems. There also may be a significant difference in system operator education and training between systems of different scale. Generally, the large systems are supervised by professionals with more extensive qualifications. This can be a matter of concern since such a large number of individuals in North America live in small communities serviced by small water systems. Some of these matters are discussed in both inquieries mentioned previously. Yet, the water acquisition, treatment and distribution system is often viewed with benign neglect by citizens and their politicians alike; most attention seems to be directed to keeping water charges low.

Many components of water systems are underground and remote; consequently, they and the whole system are not usually noticed by citizens in their daily life. Systems are taken for granted. This has allowed governments to cut back on water system financing as part of on-going cost cutting exercises. For example, it is generally agreed that the Greater Boston Area water supply system was impoverished and was refused the right by local government to increase water rates to repair and improve systems until it was taken over as a State Agency. The new Massachusetts Water Resource Authority (MWRA) has made significant steps recently to reverse this situation – but only by removing the system from local control, injecting substantial funding, and undertaking major capital works.

With the exception of the serious North Battleford and Walkerton water contamination problems noted above, citizens are primarily only concerned if they are forced to conserve water due to shortage of supply. In many cases the public view of the water situation is that the engineers need to figure out how to increase the water supply yet not increase the price. There is clear evidence that there are steadily increasing problems with water source shortage. One need only consider the chronic water shortages in the American Midwest and South, the well water shortages in Southern Ontario, the reduction of stream and river flows due to climate change, and the record low levels of the Great Lakes to understand that there is a looming critical shortage of supply. Governments have been slow to protect water sources and generally have given water supply systems minimal attention.

Lack of local government attention has led to aged water facilities that are crumbling away out of sight. Water losses are very high in such poorly maintained systems; this exacerbates the supply shortage problems because a larger volume of water must be pumped and treated just to deal with losses in the transmission and distribution systems. We now explore some of the risks, risk context and planning implications related to source of supply, bulk transmission and pretreatment, treatment, and distribution. Excluded from this discussion are the very technical engineering and hydrological risks that must be managed by good engineering in system design, building, operation and maintenance.

Risk Considerations in Supply :

Water supply comes from a variety of sources that include: lakes, rivers, wells, springs, and oceans (via desalinization plants.) Risks facing the source of supply may be divided into long term and short term ones. Long term supply risks include reduction of water tables, lake levels and stream flows due to climate change, cumulative effects of long term pollution – including deposition of airborne contaminants, cumulative effects of land use in recharge areas and upper parts of watersheds, compromised aquifer recharge areas, engineering or system failures in adjacent waste water systems, and loss of jurisdictional authority over supply areas.

There are also risks associated with excessive water consumption. Demand outstripping supply clearly leads to short term supply problems that result in water use restrictions; these can go beyond inconveniencing domestic users to the extreme of shutting down industrial operations. This can lead to firms not choosing to locate in an area or moving to an alternative jurisdiction that provides a more reliable water supply. A serious concern arises when excessive demand on water sources permanently alters the nature of the source. For example, fresh water lenses used for municipal water supply lie atop salty-groundwater in Florida and Bermuda. As long as the supply aquifers can regenerate the fresh water lenses as fast or faster than consumption, a supply of fresh water will be provided. On the other hand, excessive consumption may lead to the complete loss of the fresh water lenses – leaving only brackish water unsuitable for normal potable water consumption. This problem is not limited to the two areas mentioned; there are many other geographical areas that share a similar ground water situation.

A related and very serious risk relates to the migration of contaminants in ground water aquifers that supply potable water. These contaminants may be natural, but more often are related to present or past industrial operations or garbage landfill sites. Since water flows to fill the areas where water table is drawn down by extraction to the surface, it only makes sense that the moving water may transport contaminants and pollute a previously good water source. The Region of Waterloo, Ontario, experienced this first hand in the Town of Elmira well system. The increasing water demand by this growing community drew sufficient water out of its wells to pull dangerous contaminants in ground water from the Uniroyal Chemical plant site into several potable water wells. These wells had to be permanently removed from use, emergency water arrangements made and expensive pipelines built. In large part, these migrating chemicals related to long ago industrial processes and clean-up processes still continue.

Risks of intentional (i.e., terrorist) or accidental pollution of water sources need consideration. These could result in short term removal of the supply source. For example, a transportation accident that pollutes a river used for municipal water supply. The possibility of long term or permanent loss of supply is more unlikely; engineers argue that the normal water volumes at sources makes it unlikely that sufficient quantities of pollutant could be introduced to cause long term loss. Of course, where the source of supply is small, e.g. a well, the matter is different as revealed in the Walkerton (2001) situation and the Elmira case mentioned above.

Risk Considerations in Raw Water Transmission

Many municipalities obtain their water supply from outside their own immediate area of jurisdiction. In some cases, there may be very long supply lines indeed. Some major cities in the United States and Canada rely completely on water sources hundreds if kilometers away. For example, the greater Boston area (with population in excess of 3 million) relies completely on inland lakes half way across the State of Massachusetts; the entire supply relies on transport through a gravity fed aqueduct that is over 100 years old. Risks in raw water transmission clearly relate to the integrity of the transmission system. Risks may be posed by extreme natural events (e.g., floods and earthquakes), by cross contamination from other (e.g., Petrochemical and sewerage) high-pressure pipelines due to leakage, by structural failure, by terrorism or vandalism, or by construction accidents. The extensive length of many transmission facilities implies risks due to difficulty in monitoring activity on or near the right of way and monitoring may be compromised if the water authority does not own or have full jurisdiction over the land where the facility is sited. While easements allow an authority to run its pipes through regions, they do not provide the kind of authority over land use activity on the right of way that is required. In many cases, rights of way were established long ago, and the authority is not fully knowledgeable on the legal status of its authority. This can lead to failure to enforce desirable protection of the transmission system.

Risk Considerations in Water Treatment

Most municipal water systems treat raw water to remove contaminants that can include: organics, viruses, bacteria, sediment, and chemicals. Often this is done in one or more factory-like facilities and involves the use of heavy equipment, pumps, filers, and, in many cases, dangerous chemicals. In municipalities that rely on a distributed set of wells as their source of supply, the water treatment takes place right at the wells. Water treatment facilities are large enough to be noticed but often ignored by neighbors. These facilities are normally located within built up areas; but they may be in out-of-the-way or industrial locations where there is little oversight by public and law enforcement over a full 24 hour period. Because modern equipment control and monitoring technology is now quite reliable, many of these systems operate without on-site human supervision. This exposes such systems to risks from tampering, vandalism or terrorism from intruders.

It is beyond the scope of this paper to deal with the technical aspects of treating water sufficiently to remove contaminants. Rather we consider the broader risks associated with water treatment. The following potential risks need assessment by system planners: plant failure due to very high demand and the following intentional or accidental events: loss of electrical power to the treatment equipment, equipment failure (e.g., screens, filters, pumps, biocide systems), monitoring failure, or chemical accident. Adequate monitoring of site integrity and processes is important to manage risks; in many cases there are enough dangerous chemicals stored on site at a water treatment plan to endanger nearby residents or workers.

Risk Considerations in Potable Water Distribution

Distribution of treated water to residences, commerce and industry involves a large network of trunk and local pipelines, valves, reservoirs and standpipes. High and low pressure systems are involved. Normally distribution areas are divided into zones that are supplied from several trunks. Many of these systems have been developed incrementally over long periods of time and may have a large mix of old and new technology – some in poor and some in good condition. Some parts require real-time monitoring and control, other parts operate independently and only receive attention on an exception (i.e., emergency) basis. It is beyond this paper to discuss the engineering design and operating aspects of these systems. Again, we consider here the wider set of risks – particularly those that relate to land use or activity on the land.

<u>Cross Contamination in Distribution:</u>

Water distribution systems coexist in close proximity to a wide variety of below-grade utilities. In some cases, sections of these systems are virtually "dead" areas with little or low flow. (These pose real problems in the event that a water distribution system needs to be decontaminated. The Walkerton case, it took several months to fully decontaminate the distribution system.) Proximity to the other below-grade services and the presence of some low pressure low flow water pipes exposes a risk of possible cross contamination from leakage of external materials into the water distribution system from other (dangerous to water but) legitimate utilities. There is further increase in risk if a low-pressure part of a distribution system passes through an industrial area where there are many buried pipes carrying chemicals and where the presence of heavy traffic could increase the probability of leaks. Prevention of cross contamination problems requires good cooperation from industry, accurate documentation of pipe locations contents and pressures, and an effective monitoring system.

Industry and neighboring utilities are not the only potential risk sources for cross contamination. Residential and commercial users are normally viewed as "very low pressure" systems and are therefore usually seen by systems designers only as "sinks" or consumption points. Most systems simply assume that water will only flow from the higher-pressure distribution mains into the service location; in most if not all cases, there is no equipment installed to prevent an (unexpected) reverse flow. There is a risk that a commercial or even residential service location could back-feed water or other materials into the distribution system if the pressure on the service end was raised sufficiently. This appears to be the main risk factor for water distribution system poisoning by accidental or intentional (i.e., terrorist) means. It seems remarkable to this author that it is not common practice for municipalities to install check valves for every consumer connection at the main exterior shut off (owned by the municipality) to prevent back-feed possibilities.

<u>Distribution System Breakdown</u>

Likely this is the most frequent water system problem seen by end users. Often system break down is due to an isolated pipe or valve rupture or a loss of electrical power to a wide area. The consequences are usually benign and repaired quickly. Construction near water distribution systems can lead to this kind of problem particularly if the actual location of piping is not well documented. Pipe failure can also result from the freeze/thaw seasonal cycle and vibration from heavy rail or road traffic. Distribution systems rely on water pressure differential maintained by electric pumps. It is remarkable that many water distribution systems do not have facilities in place to deal with major electric power outages. This was clearly evident as a problem in the Eastern Canada Ice Storm (Newkirk, 2001); yet many municipalities have not taken steps to provide power back-up systems. Situations are known to the author where the residents of whole subdivisions have been left without any water supply for several days due to a power outage. Minimizing distribution break down risk probability is very important due to safety implications related to both health and fire protection.

Water Risk Considerations for Planners

Through the previous discussion a number of land use and governance considerations were identified. This leads to recommendations that planners take an active role in identifying, quantifying and discussing the associated risks to community water systems. Further the following suggestions are made to encourage more planner contributions to the water risk discussion.

<u>Supply Considerations:</u>

Planners need to assist in the determination of land tenure and the jurisdictional authority over the water source(s). Once determined, planners need to develop approaches to buffer the sources from possible contamination. (This could include steps to impose strong controls on large scale livestock farms (Newkirk, 2001)) Most communities do not have adequate information on the ground water resources and flows. Planners need to require ground water studies as part of the evidence considered in review of new development proposals. The area's history of possible point sources of land-based contamination is usually poorly documented; this makes it nearly impossible to identify the potential for contamination problems of increased water harvesting. Planners need to commission historical studies to locate old landfills and industrial sites; these need to be built into a risk assessment GIS database for the community. Planners must include water demand (and wastewater treatment requirements) tied to their usual population and employment forecasts. An interpretation of this demand against the available resources and system capabilities should become part of an annual reporting of risks to government.

<u>Raw Water Transmission:</u>

Planners need to assist in the determination of land tenure and the jurisdictional authority over the rights of way used to transport bulk raw water to treatment plants. Once determined, planners need to map and then develop regulations to buffer the rights of way from nearby negative land use or activities. This may require acquisition of land to convert rights of way easements to ownership. Accurate GIS mapping of piping and associated physical plant should be added to the regional database. Planners should work with system engineers to ensure a basic level of redundancy in routing of bulk water transmission. This should be part of normal regional strategic planning processes to ensure adequate provision of rights of way for the future and to incrementally enhance system redundancy and robustness over the long term.

Water Treatment:

Planners need to recognize that water treatment plants contain hazardous chemicals and processes; treatment plants should be treated in the same manner as other industrial plants regarding safety set backs and site planning requirements. Planners should work with water system designers to ensure that water treatment is distributed spatially within a community to minimize the effect of an unintentional or intentional event at a treatment facility that would require it to go off-line leaving numbers of people without treated water (or possibly without water.) For example, the MWRA 's new state-of-the-art water treatment plant is designed to treat the entire water supply to the Greater Boston Area. This creates an unnecessary level of vulnerability for the whole region to one major event. To improve community overview (more eyes on the street) there may be benefit of having areas like water treatment plants and reservoirs developed as actively used parks to increase the surveillance of facilities by the public.

Distribution Systems:

To reduce the risk of contamination by consumers back-feeding contaminants into the distribution system (and reducing the potential for terrorist activity), planners should arrange revisions of water connection standards to require a check valve at the municipal shut off valve for every consumer service connection. All site plan review by planners should include evaluation of all below grade utilities in consultation for municipal engineers. Any changes to existing utilities or development of new utilities should be by permit after review of detailed location information and identification of the properties of any potential contaminants contained therein. This information should be inventoried in the planning GIS database. Planners should conduct risk assessments of the possible impacts on water systems of substantially increased road or rail traffic or new transportation developments. In cooperation with municipal engineers, planners should conduct historical surveys to assemble information on below grade utilities – especially in industrial or previously industrial areas. Such information should be considered during the review of all site plans related to brown fields redevelopment.

Conclusion:

This discussion has identified a number of possible water system risks that need investigation by planners – often in cooperation with municipal engineers. There is need to add significant information to the planning GIS database. There is also need to better understand and deal with the ownership and jurisdiction over the land used by municipal water systems. It has been argued that many water system risks are more than simply engineering problems and that planners have an important role in better understanding, and, hopefully, mitigating the risks facing those millions of people who depend upon municipal water supply systems.

References:

Newkirk, Ross T., 1995. "Linking GIS and Storm Water Modeling for Emergency Risk Assessment", *The International Emergency Management and Engineering Conference.* San Diego: Society for Computer Simulation. Pp. 480-485.

Newkirk, Ross T., 1996. "Modeling Storm Water Risks of Alternative Planned Developments by Combining GIS and Hydrology", *The International Emergency Management and Engineering Conference.* Sophia Antipolis, FR.: Ecole De Mines de Paris. Pp. 153-164.

Newkirk, Ross T., 1997. "Design Stage Modeling Requirements for Reducing Storm Water Quantity and Quality Risks of Urban Development", *The International Emergency Management Conference.* Copenhagen: Riso National Laboratory. Pp. 175-183.

Newkirk, R. T., 1999a. "Emergency Mitigation and Preparedness: A Challenge for Municipal Planners." *The International Emergency Management Conference.* Delft, Netherlands: Delft University of Technology. Pp. 515-528.

Newkirk, R. T., 1999b. "Reducing Downstream Storm Water Impacts Using Design Stage Modeling In Urban Development," *Environments.* Vol. 28, No. 1, pp. 65-74.

Newkirk, R. T., 2000. "Reducing Flood Disasters: The Need for Effective Local Planning," *The International Emergency Management Conference.* Washington: The George Washington University. Pp. 469-484.

Newkirk, R. T., 2001. "Avoiding Flood Disasters: Two Important Considerations for Planners," *The International Emergency Management Conference.* Oslo, 2001: The University of Waterloo, Waterloo, Canada, in press.

Newkirk, R. T., 2001. "The Increasing Cost of Disasters in Developed Countries: A Challenge to Local Planning and Government." *Journal of Contingencies and Crisis Management.* Vol. 9, No. 3. Pp. 159-170.

North Battleford, 2001. Mr. Justice Robert Lang Commissioner, www.northbattlefordwaterinquiery.ca.

Walkerton, 2001. Honorable Dennis R. O'Connor, Commissioner, www.walkertoninquiery.com.