

C A Bacterial Contamination of a Public Water Supply

In May 2000, in the small town of Walkerton, Ontario, Canada, some contaminants, largely *Escherichia coli* O157:H7 (the common abbreviation for which is *E. coli*) and *Campylobacter jejuni* entered the Walkerton water system through a municipal well. About half the people in the town of 4,800 became ill, and seven died [147]. The proximate events are presented first and then the STAMP analysis of the accident.

C.1 Proximate Events at Walkerton

The Walkerton Public Utilities Commission (WPUC) operated the Walkerton water system. Stan Koebel was the WPUC's general manager and his brother Frank its foreman. In May 2000, the water system was supplied by three groundwater sources: Wells 5, 6, and 7. The water pumped from each well was treated with chlorine before entering the distribution system.

The source of the contamination was manure that had been spread on a farm near Well 5. Unusually heavy rains from May 8 to May 12 carried the bacteria to the well. Between May 13 and May 15, Frank Koebel checked Well 5 but did not take measurements of chlorine residuals, although daily checks were supposed to be made.¹ Well 5 was turned off on May 15.

On the morning of May 15, Stan Koebel returned to work after having been away from Walkerton for more than a week. He turned on Well 7, but shortly after doing so, he learned a new chlorinator for Well 7 had not been installed, and the well was therefore pumping unchlorinated water directly into the distribution system. He did not turn off the well but instead allowed it to operate without chlorination until noon on Friday May 19, when the new chlorinator was installed.

1. Low chlorine residuals are a sign that contamination is overwhelming the disinfectant capacity of the chlorination process.

On May 15, samples from the Walkerton water distribution system were sent to A&L Labs for testing according to the normal procedure. On May 17, A&L Labs advised Mr. Koebel that samples from May 15 tested positive for *E. coli* and total coliforms. The next day, May 18, the first symptoms of widespread illness appeared in the community. Public inquiries about the water prompted assurances by Stan Koebel that the water was safe. By May 19 the scope of the outbreak had grown, and a pediatrician contacted the local health unit with a suspicion that she was seeing patients with symptoms of *E. coli*.

The Bruce–Grey–Owen Sound (BGOS) Health Unit, which is the government unit responsible for public health in the area, began an investigation. In two separate calls placed to Stan Koebel, the health officials were told that the water was “okay.” At that time, Stan Koebel did not disclose the lab results from May 15, but he did start to flush and superchlorinate the system to try to destroy any contaminants in the water. The chlorine residuals began to recover. Apparently, Mr. Koebel did not disclose the lab results for a combination of two reasons: he did not want to reveal the unsafe practices he had engaged in from May 15 to May 17 (i.e., running Well 7 without chlorination), and he did not understand the serious and potentially fatal consequences of the presence of *E. coli* in the water system. He continued to flush and superchlorinate the water through the following weekend, successfully increasing the chlorine residuals. Ironically, it was not the operation of Well 7 without a chlorinator that caused the contamination; the contamination instead entered the system through Well 5 from May 12 until it was shut down on May 15.

On May 20, the first positive test for *E. coli* infection was reported, and the BGOS Health Unit called Stan Koebel twice to determine whether the infection might be linked to the water system. Both times, Stan Koebel reported acceptable chlorine residuals and failed to disclose the adverse test results. The Health Unit assured the public that the water was safe based on the assurances of Mr. Koebel.

That same day, a WPUC employee placed an anonymous call to the Ministry of the Environment (MOE) Spills Action Center, which acts as an emergency call center, reporting the adverse test results from May 15. On contacting Mr. Koebel, the MOE was given an evasive answer and Mr. Koebel still did not reveal that contaminated samples had been found in the water distribution system. The health unit contacted the Local Medical Officer, and he took over the investigation. The health unit took its own water samples and delivered them to the Ministry of Health laboratory in London (Ontario) for microbiological testing.

When asked by the MOE for documentation, Stan Koebel finally produced the adverse test results from A&L Laboratory and the daily operating sheets for Wells 5 and 6, but said he could not produce the sheet for Well 7 until the next day. Later, he instructed his brother Frank to revise the Well 7 sheet with the intention of concealing the fact that Well 7 had operated without a chlorinator. On Tuesday, May

23, Stan Koebel provided the altered daily operating sheet to the MOE. That same day, the health unit learned that two of the water samples it had collected on May 21 had tested positive for *E. coli*.

Without waiting for its own samples to be returned, on May 21 the BGOS health unit issued a boil-water advisory on local radio. About half of Walkerton's residents became aware of the advisory on May 21, with some members of the public still drinking the Walkerton town water as late as May 23. The first person died on May 22, a second on May 23, and two more on May 24. During this time, many children became seriously ill and some victims will probably experience lasting damage to their kidneys as well as other long-term health effects. In all, seven people died, and more than 2,300 became ill.

Looking only at these proximate events and connecting them by some type of causal chain, it appears that this is a simple case of incompetence, negligence, and dishonesty by WPUC employees. In fact, the government representatives argued at the accident inquiry that Stan Koebel and the WPUC were solely responsible for the outbreak and that they were the only ones who could have prevented it. In May 2003, exactly three years after the accident, Stan and Frank Koebel were arrested for their part in the loss. But a systems-theoretic analysis using STAMP provides a much more informative and useful understanding of the accident besides simply blaming it only on the actions of the Koebel brothers.

C.2 System Hazards, System Safety Constraints, and Control Structure

As in the previous examples, the first step in creating a STAMP analysis is to identify the system hazards, the system safety constraints, and the hierarchical control structure in place to enforce the constraints.

The system hazard related to the Walkerton accident is public exposure to *E. coli* or other health-related contaminants through drinking water. This hazard leads to the following system safety constraint:

The safety control structure must prevent exposure of the public to contaminated water.

- 1. Water quality must not be compromised.*
- 2. Public health measures must reduce risk of exposure if water quality is compromised (e.g., boil-water advisories).*

Each component of the sociotechnical public water system safety control structure (figure C.1) plays a role in enforcing this general system safety constraint and will, in turn, have its own safety constraints to enforce that are related to its function in the overall system. For example, the Canadian federal government is responsible

for establishing a nationwide public health system and ensuring it is operating effectively. Federal guidelines are provided to the provinces, but responsibility for water quality is primarily delegated to each individual province.

The provincial governments are responsible for regulating and overseeing the safety of the drinking water. They do this by providing budgets to the ministries involved—in Ontario these are the Ministry of the Environment (MOE), the Ministry of Health (MOH), and the Ministry of Agriculture, Food, and Rural Affairs—and by passing laws and adopting government policies affecting water safety.

According to the report on the official Inquiry into the Walkerton accident [147], the Ministry of Agriculture, Food, and Rural Affairs in Ontario is responsible for regulating agricultural activities with potential impact on drinking water sources. In fact, there was no watershed protection plan to protect the water system from agricultural runoff. Instead, the MOE was responsible for ensuring that the water systems could not be affected by such runoff.

The MOE has primary responsibility for regulating and for enforcing legislation, regulations, and policies that apply to the construction and operation of municipal water systems. Guidelines and objectives are set by the MOE, based on federal guidelines. They are enforceable through certificates of approval issued to public water utilities operators under the Ontario Water Resources Act. The MOE also has legislative responsibility for building and maintaining water treatment plants and has responsibility for public water system inspections and drinking water surveillance, for setting standards for certification of water systems, and for continuing education requirements for operators to maintain competence as knowledge about water safety increases.

The MOH supervises local health units, in this case, the Bruce–Grey–Owen Sound (BGOS) Department of Health, run by local officers of health. BGOS receives inputs from various sources, including hospitals, the local medical community, the MOH, and the WPUC, and in turn is responsible for issuing advisories and alerts if required to protect public health. Upon receiving adverse water quality reports from the government testing labs or the MOE, the local public health inspector in Walkerton would normally contact the WPUC to ensure that follow-up samples were taken and chlorine residuals maintained.

The public water system in Walkerton is run by the WPUC, which operates the wells and is responsible for chlorination and for measurement of chlorine residuals. Oversight is provided by elected commissioners. The commissioners are responsible for establishing and controlling the policies under which the WPUC operates, while the general manager (Stan Koebel) and staff are responsible for administering these policies in operating the water facility. Although theoretically also responsible for the public water system, the municipality left the operation of the water system to the WPUC.

Together, the safety constraints enforced by all of these system control components must be adequate to enforce the overall system safety constraints. Figure C.1 shows the overall theoretical water safety control structure in Ontario and the safety-related requirements and constraints for each system component.

Each component of the sociotechnical public water safety system plays a role in enforcing the system safety constraints. Understanding the accident requires again understanding the role in the accident scenario played by each level of the system's hierarchical control structure in the accident by not adequately enforcing its part of the safety constraint. For each component, the contribution to the accident is described in terms of the four conditions required for adequate control: the goal, the actions, the process or mental models, and feedback. At each level of control, the context in which the behaviors took place is also considered. It is not possible to understand human behavior without knowing the context in which it occurs and the behavior-shaping factors in the environment.

This first level of analysis provides a view of the limitations of the static control structure at the time of the accident. But systems are not static—they adapt and change over time. In STAMP, systems are treated as a dynamic process that is continually adapting to achieve its ends and to react to changes in itself and its environment. The original system design must not only enforce the system safety constraints, but the system must continue to enforce the constraints as changes occur. The analysis of accidents, therefore, requires understanding not only the flaws in the static control structure that allowed the safety constraints to be violated but also the changes to the safety control structure over time (the *structural dynamics*) and the dynamic processes behind these changes (the *behavioral dynamics*). Section C.8 analyzes the structural dynamics of the Walkerton accident.

C.3 Physical Process View of the Accident

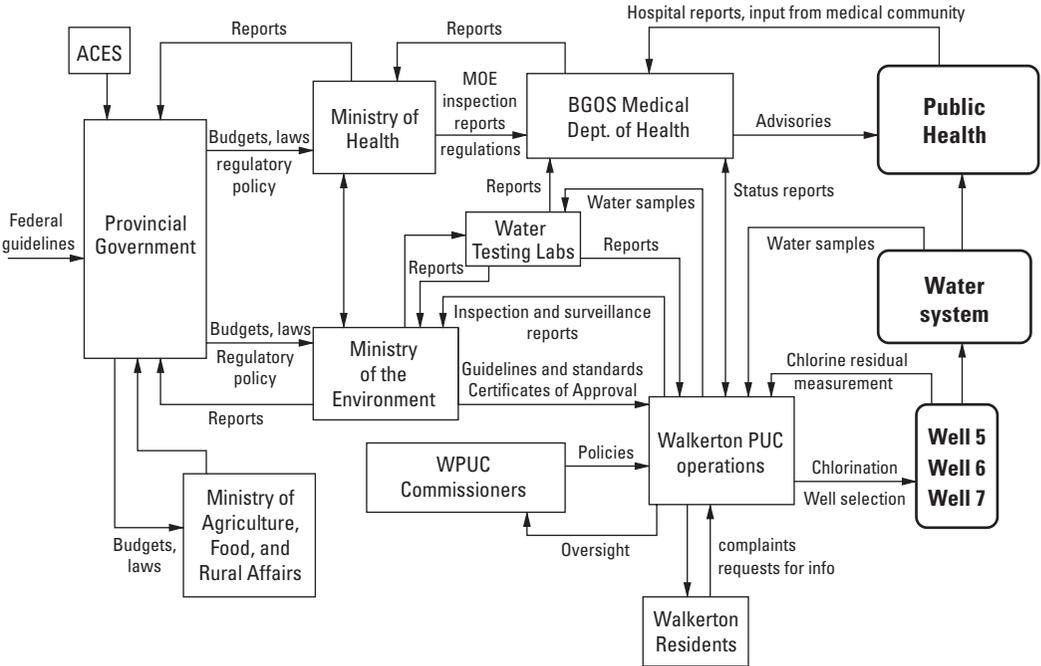
As in other component interaction accidents, there were no physical failures involved. If, as in figure C.2, we draw the boundary of the physical system around the wells, the public water system, and public health, then one can describe the “cause” of the accident at the physical system level as the inability of the physical design to enforce the physical safety constraint in the face of an environmental disturbance, in this case the unusually heavy rains that resulted in the transport of contaminants from the fields to the water supply. The safety constraint being enforced at this level is that water must be free from unacceptable levels of contaminants.

Well 5 was a very shallow well: all of its water was drawn from an area between 5m and 8m below the surface. More significantly, the water was drawn from an area of bedrock, and the shallowness of the soil overburden above the bedrock along

System Hazard: Public is exposed to *E. coli* or other health related contaminants through drinking water.

System Safety Constraints: The safety control structure must prevent exposure of the public to contaminated water.

- (1) Water quality must not be compromised.
- (2) Public health measures must reduce risk of exposure if water quality is compromised (e.g., notification and procedures to follow)



Safety Requirements and Constraints:

Federal Government

- Establish a nationwide public health system and ensure it is operating effectively.

Provincial Government

- Establish regulatory bodies and codes of responsibilities, authority, and accountability
- Provide adequate resources to regulatory bodies to carry out their responsibilities.
- Provide oversight and feedback loops to ensure that provincial regulatory bodies are doing their job adequately.
- Ensure adequate risk assessment is conducted and effective risk management plans are in place.

Ministry of the Environment

- Ensure that those in charge of water supplies are competent to carry out their responsibilities.
- Perform inspections and surveillance. Enforce compliance if problems found.
- Perform hazard analyses to identify vulnerabilities and monitor them.
- Perform continual risk evaluation for existing facilities and establish new controls if necessary.
- Establish criteria for determining whether a well is at risk.
- Establish feedback channels for adverse test results. Provide multiple paths.
- Enforce legislation, regulations and policies applying to construction and operation of municipal water systems.
- Establish certification and training requirements for water system operators.

ACES

- Provide stakeholder and public review and input on ministry standards

Ministry of Health

- Ensure adequate procedures exist for notification and risk abatement if water quality is compromised.

Water Testing Labs

- Provide timely reports on testing results to MOE, PUC, and Medical Dept. of Health

WPUC Commissioners

- Oversee operations to ensure water quality is not compromised.

WPUC Operations Management

- Monitor operations to ensure that sample taking and reporting is accurate and adequate chlorination is being performed.

WPUC Operations

- Measure chlorine residuals.
- Apply adequate doses of chlorine to kill bacteria.

BGOS Medical Department of Health

- Provide oversight of drinking water quality.
- Follow up on adverse drinking water quality reports.
- Issue boil water advisories when necessary.

Figure C.1

The basic water safety control structure. Lines going into the left of a box are control lines. Lines from or to the top or bottom of a box represent information, feedback, or a physical flow. Rectangles with sharp corners are controllers, while rectangles with rounded corners represent plants.

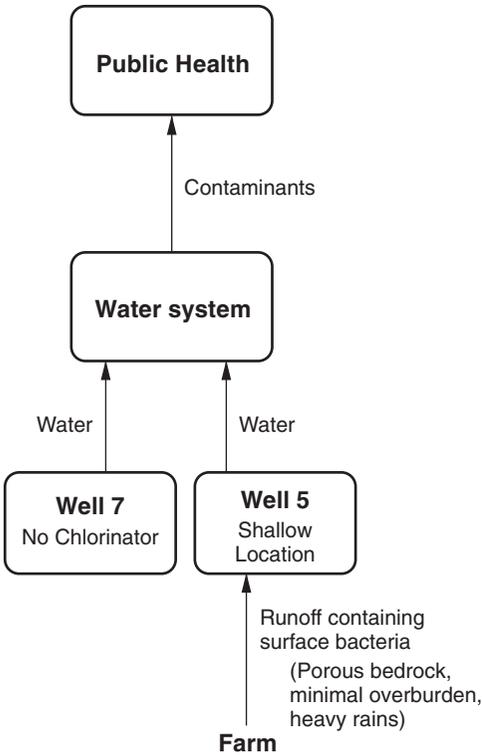


Figure C.2
The physical components of the water safety control structure.

with the fractured and porous nature of the bedrock itself made it possible for surface bacteria to make its way to Well 5.

C.4 First-Level Operations

Besides the physical system analysis, most hazard analysis techniques and accident investigations consider the immediate operators of the system. Figure C.3 shows the results of a STAMP analysis of the flaws by the lower operations levels at Walkerton that were involved in the accident.

The safety requirements and constraints on the operators of the local water system were that they must apply adequate doses of chlorine to kill bacteria and must measure chlorine residuals. Stan Koebel, the WPUC manager, and Frank Koebel, its foreman, were not qualified to hold their positions within the WPUC. Before 1993, there were no mandatory certification requirements, and after 1993 they were certified through a grandfathering process based solely on experience.

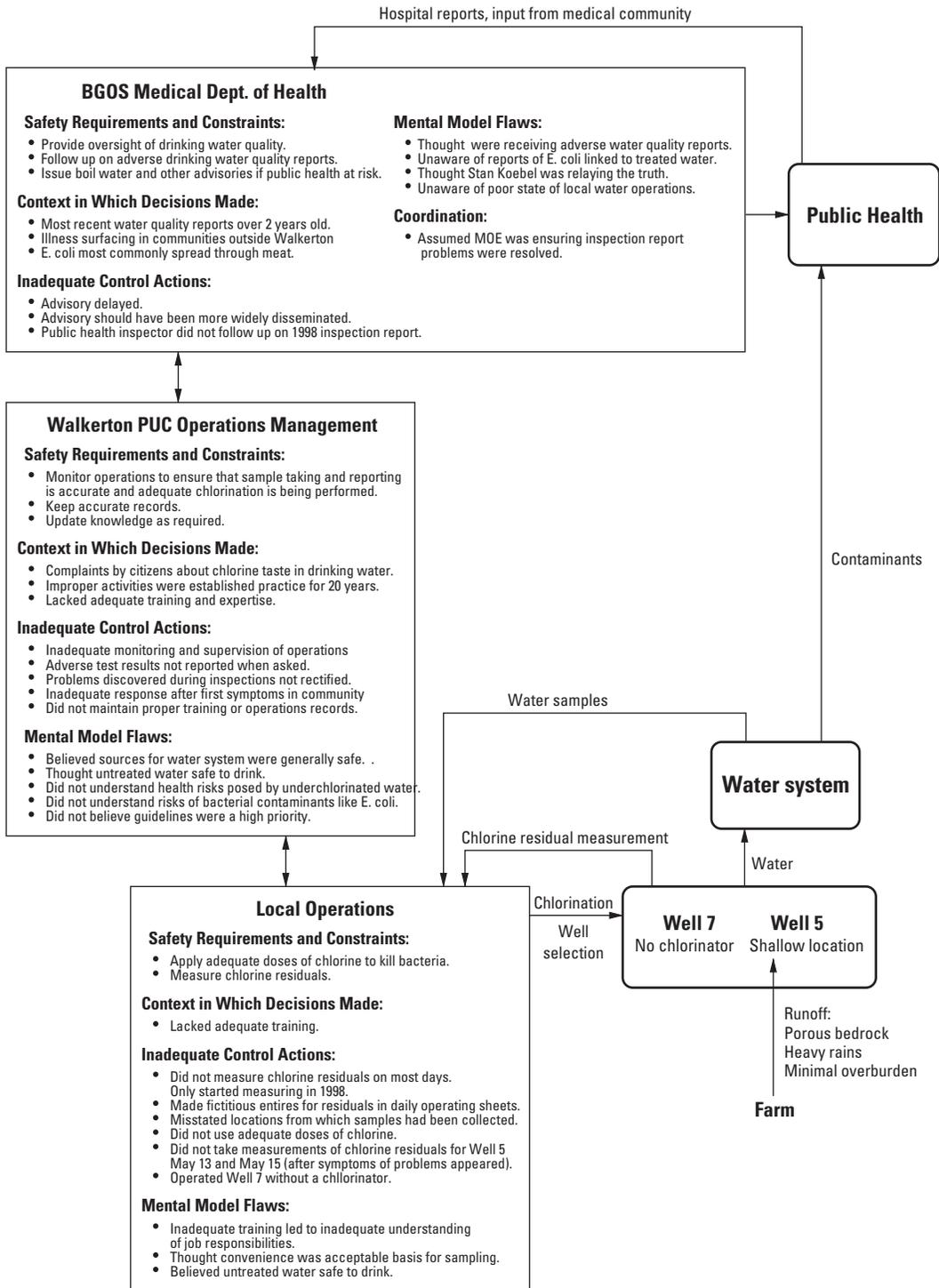


Figure C.3

The physical and operational components of the water safety control structure.

Stan Koebel knew how to operate the water system mechanically, but he lacked knowledge about the health risks associated with a failure to properly operate the system and of the importance of following the requirements for treatment and monitoring of the water quality. The inquiry report stated that many improper operating practices had been going on for years before Stan Koebel became manager: He simply left them in place. These practices, some of which went back twenty years, included misstating the locations at which samples for microbial testing were taken, operating wells without chlorination, making false entries in daily operating sheets, not measuring chlorine residuals daily, not adequately chlorinating the water, and submitting false annual reports to the MOE.

The operators of the Walkerton water system did not intentionally put the public at risk. Stan Koebel and the other WPUC employees believed the untreated water was safe and often drank it themselves at the well sites. Local residents also pressed the WPUC to decrease the amount of chlorine used because they objected to the taste of chlorinated water.

A second first-level control component was the local health units, in this case, the BGOS Department of Health. Local health units are supervised by the MOH and run by local Officers of Health to execute their role in protecting public health. The BGOS Medical Department of Health receives inputs (feedback) from various sources, including hospitals, the local medical community, the MOH, and the WPUC, and in turn is responsible for issuing advisories and alerts if required to protect public health. While the local health unit did issue a boil-water advisory on local radio, when it finally decided that the water system might be involved, this means of notifying the public was not very effective. Other more effective means could have been employed. One reason for the delay was simply that evidence was not strong that the water system was the source of the contamination. *E. coli* is most often spread by meat, which is why it is commonly called the “hamburger disease.” In addition, some reported cases of illness came from people who did not live in the Walkerton water district. Finally, the local health inspector had no reason to believe that there were problems with the way the Walkerton water system was operated.

An important event related to the accident occurred in 1996, when the government water testing laboratories were privatized. Previously, water samples were sent to government laboratories for testing. These labs then shared the results with the appropriate government agencies as well as the local operators. Upon receiving adverse water quality reports from the government testing labs or the MOE, the local public health inspector in Walkerton would contact the WPUC to ensure that follow-up samples were taken and chlorine residuals maintained.

After water testing laboratory services for municipalities were assumed by the private sector in 1996, the MOH health unit for the Walkerton area sought assurances from the MOE’s local office that it would continue to be notified of all adverse

water quality results relating to community water systems. It received that assurance, both in correspondence and at a meeting, but it did not receive adverse water test reports. Without feedback about any problems in the water system, the local public health authorities assumed everything was fine.

In fact, there *were* warnings of problems. Between January and April of 2000 (the months just prior to the May *E. coli* outbreak), the lab that tested Walkerton's water repeatedly detected coliform bacteria—an indication that surface water was getting into the water supply. The lab notified the MOE on five separate occasions. The MOE in turn phoned the WPUC, was assured the problems were being fixed, and let it go at that. The MOE did not inform the local Walkerton Medical Office of Health, however, as by law it was required to do.

The WPUC changed water-testing laboratories in May 2000. The new laboratory, A&L Canada Laboratories East, was unaware of any notification guidelines. In fact, they considered test results to be confidential and thus improper to send to anyone but the client (in this case, the WPUC manager Stan Koebel).

In 1998, the BGOS health unit did receive a report on an MOE inspection of the Walkerton water system that showed some serious problems did exist. When the local Walkerton public health inspector read the report, he filed it, assuming that the MOE would ensure that the problems identified were properly addressed. Note the coordination problems here in an area of overlapping control. Both the MOE and the local public health inspector should have followed up on the 1998 inspection report, but there was no written protocol instructing the public health inspector on how to respond to adverse water quality or water system inspection reports. The MOE also lacked such protocols. Once again, the local public health authorities received no feedback that indicated water system operations were problematic.

Looking only at the physical system and local operations, it appears that the accident was simply the result of incompetent water system operators, who initially lied to protect their jobs (but who were unaware of the potentially fatal consequences of their lies) made worse by an inadequate response by the local health unit. If the goal is to find someone to blame, this conclusion is reasonable. If, however, the goal is to understand why the accident occurred in order to make effective changes (beyond simply firing the Koebel brothers) in order to prevent repetitions in the future or to learn how to prevent accidents in other situations, then a more complete study of the larger water safety control structure within which the local operations is embedded is necessary.

C.5 Municipal Government

Figure C.4 summarizes the flaws in the municipal water system control structure that allowed the dysfunctional interactions and thus the accident to occur.

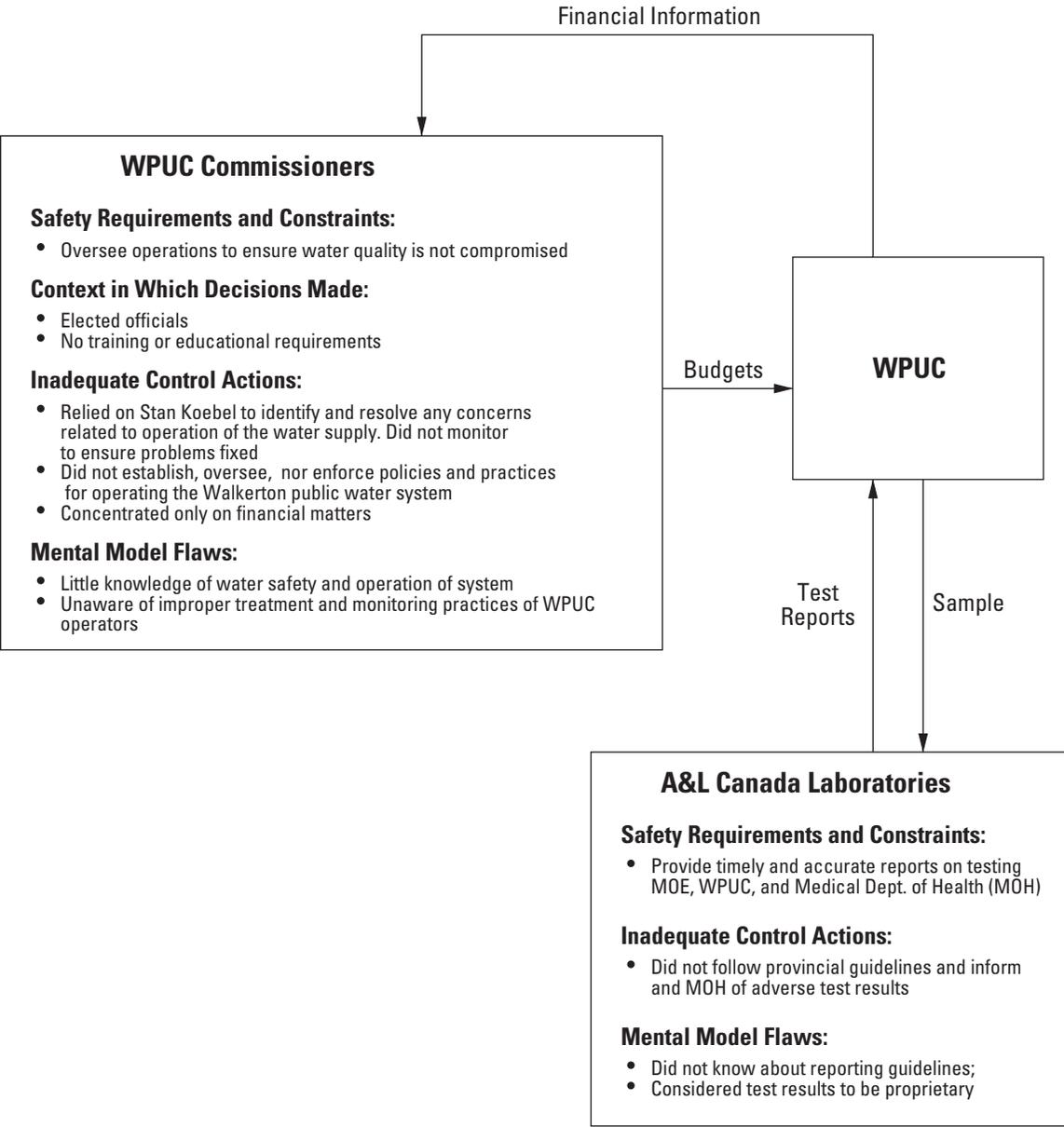


Figure C.4
The municipal control structure and its contribution to the accident.

Operating conditions on the public water system should theoretically have been imposed by the municipality, the WPUC commissioners, and the WPUC manager. The municipality left the operation of the water system to the WPUC. The commissioners, who were elected, over the years became more focused on the finances of the PUC than the operations. They had little or no training or knowledge of water system operations or even water quality itself. Without such knowledge and with their focus on financial issues, they gave all responsibility for operations to the manager of the WPUC (Stan Koebel) and provided no other operational oversight.

The WPUC commissioners received a copy of the 1998 inspection report but did nothing beyond asking for an explanation from Stan Koebel and accepting his word that he would correct the deficient practices. They never followed up to make sure he did. The mayor of Walkerton and the municipality also received the report but they assumed the WPUC would take care of the problems.

C.6 Provincial Regulatory Agencies (Ministries)

The MOE has primary responsibility for regulating and for enforcing legislation, regulations, and policies that apply to the construction and operation of municipal water systems. Guidelines and objectives are set by the MOE, based on federal guidelines that are enforceable through certificates of approval issued to public water utility operators.

Walkerton Well 5 was built in 1978 and issued a certificate of approval by the MOE in 1979. Despite potential problems—the groundwater supplying the well was recognized as being vulnerable to surface contamination—no explicit operating conditions were imposed at the time.

Although the original certificate of approval for Well 5 did not include any special operating conditions, over time MOE practices changed. By 1992, the MOE had developed a set of model operating conditions for water treatment and monitoring that were routinely attached to new certificates of approval for municipal water systems. There was no effort, however, to determine whether such conditions should be attached to existing certificates, such as the one for Well 5.

The provincial water quality guidelines were amended in 1994 to require the continuous monitoring of chlorine residuals and turbidity for wells supplied by a groundwater source that was under the direct influence of surface water (as was Walkerton's Well 5). Automatic monitoring and shutoff valves would have mitigated the operational problems at Walkerton and prevented the deaths and illness associated with the *E. coli* contamination in May 2000 if the requirement had been enforced in existing wells. However, at the time, there was no program or policy to review existing wells to determine whether they met the requirements for continuous monitoring. In addition, MOE inspectors were not directed to notify well

Ministry of the Environment

Safety Requirements and Constraints:

- Ensure those in charge of water supplies are competent to carry out their responsibilities.
- Perform inspections and enforce compliance if problems found.
- Perform hazard analyses to provide information about where vulnerabilities are and monitor them.
- Perform continual risk evaluation of existing facilities and establish new controls if necessary.
- Establish criteria for determining whether a well is at risk.
- Establish feedback channels for adverse test results. Provide multiple paths so that dysfunctional paths cannot prevent reporting.
- Enforce legislation, regulations, and policies applying to construction and operation of municipal water systems.
- Establish certification and training requirements for water system operators.

Context in Which Decisions Made:

- Critical information about history of known vulnerable water sources not easily accessible.
- Budget cuts and staff reductions.

Inadequate Control Actions:

- No legally enforceable measures taken to ensure that concerns identified in inspections are addressed. Weak response to repeated violations uncovered in periodic inspections.
- Relied on voluntary compliance with regulations and guidelines.
- No systematic review of existing certificates of approval to determine if conditions should be added for continuous monitoring.
- Did not retroactively apply new approvals program to older facilities when procedures changed in 1992.
- Did not require continuous monitoring of existing facilities when ODWO amended in 1994.
- MOE inspectors not directed to assess existing wells during inspections.
- MOE inspectors not provided with criteria for determining whether a given well was at risk. Not directed to examine daily operating sheets.
- Inadequate inspections and improperly structured and administered inspection program.
- Approval of Well 5 without attaching operating conditions or special monitoring or inspection requirements.
- No followup on inspection reports noting serious deficiencies.
- Did not inform Walkerton Medical Officer of Health about adverse test results in January to April 2000 as required to do.
- Private labs not informed about reporting guidelines.
- No certification or training requirements for grandfathered operators.
- No enforcement of continuing training requirements.
- Inadequate training of MOE personnel.

Mental Model Flaws:

- Incorrect model of state of compliance with water quality regulations and guidelines.
- Several local MOE personnel did not know *E. coli* could be fatal.

Feedback:

- Did not monitor effects of privatization on reporting of adverse test results.
- Inadequate feedback about state of water quality and water test results.

Coordination:

- Neither MOE nor MOH took responsibility for enacting notification legislation.

Ministry of Health

Safety Requirements and Constraints:

- Ensure adequate procedures exist for notification and risk abatement if water quality is compromised.

Inadequate Control Actions:

- No written protocol provided to local public health inspector on how to respond to adverse water quality or inspection reports.

Coordination:

- Neither MOE nor MOH took responsibility for enacting notification legislation.

Figure C.5

The role of the ministries in the accident.

operators (like the Koebel brothers) of the new requirement or to assess during inspections if a well required continuous monitoring.

Stan and Frank Koebel lacked the training and expertise to identify the vulnerability of Well 5 themselves and to understand the resulting need for continuous chlorine residual and turbidity monitors. After the introduction of mandatory certification in 1993, the Koebel brothers were certified on the basis of experience even though they did not meet the certification requirements. The new rules also required forty hours of training a year for each certified operator. Stan and Frank Koebel did not take the required amount of training, and the training they did take did not adequately address drinking water safety. The MOE did not enforce the training requirements and did not focus the training on drinking water safety.

The Koebel brothers and the Walkerton commissioners were not the only ones with inadequate training and knowledge of drinking water safety. Evidence at the inquiry showed that several environmental officers in the MOE's local office were unaware that *E. coli* was potentially lethal and their mental models were also incorrect with respect to other matters essential to water safety.

At the time of the privatization of the government water testing laboratories in 1996, the MOE sent a guidance document to those municipalities that requested it. The document strongly recommended that a municipality include in any contract with a private lab a clause specifying that the laboratory directly notify the MOE and the local medical officer of health about adverse test results. There is no evidence that the Walkerton PUC either requested or received this document. The MOE had no mechanism for informing private laboratories of the existing guidelines for reporting adverse results to the MOE and the MOH.

In 1997, the MOH took the unusual step of writing to the MOE requesting that legislation be amended to ensure that the proper authorities would be notified of adverse water test results. The MOE declined to propose legislation, indicating that the existing guidelines dealt with the issue. On several occasions, officials in the MOH and the MOE expressed concerns about failures to report adverse test results to local medical officers of health in accordance with the protocol. But the anti-regulatory culture and the existence of the Red Tape Commission discouraged any proposals to make notification legally binding on the operators or municipal water systems and private labs.

Another important impact of the 1996 law was a reduction in the MOE water system inspection program. The cutbacks at the MOE negatively impacted the number of inspections, although the inspection program had other deficiencies as well.

The MOE inspected the Walkerton water system in 1991, 1995, and 1998. At the time of the inspections, problems existed relating to water safety. Inspectors identified some of them, but unfortunately two of the most significant problems—the

vulnerability of Well 5 to surface contamination and the improper chlorination and monitoring practices of the WPUC—were not detected. Information about the vulnerability of Well 5 was available in MOE files, but inspectors were not directed to look at relevant information about the security of water sources and the archived information was not easy to find. Information about the second problem, improper chlorination and monitoring practices of the WPUC, was there to be seen in the operating records maintained by the WPUC. The Walkerton inquiry report concludes that a proper examination of the daily operating sheets would have disclosed the problem. However, the inspectors were not instructed to carry out a thorough review of operating records.

The 1998 inspection report did show there had been problems with the water supply for years: detection of *E. coli* in treated water with increasing frequency, chlorine residuals in treated water at less than the required 0.5 mg/L, noncompliance with minimum bacteriological sampling requirements, and not maintaining proper training records.

The MOE outlined improvements that should be made, but desperately short of inspection staff and faced with small water systems across the province that were not meeting standards, it never scheduled a follow-up inspection to see if the improvements were in fact being carried out. The Walkerton inquiry report suggests that the use of guidelines rather than regulations had an impact here. The report states that had the WPUC been found to be in noncompliance with a legally enforceable regulation, as opposed to a guideline, it is more likely that the MOE would have taken stronger measures to ensure compliance—such as the use of further inspections, the issuance of a director's order (which would have required the WPUC to comply with the requirements for treatment and monitoring), or enforcement proceedings. The lack of any follow-up or enforcement efforts may have led the Koebel brothers to believe the recommendations were not very important, even to the MOE.

Between January and April of 2000 (the months just prior to the May *E. coli* outbreak), the lab that tested Walkerton's water repeatedly detected coliform bacteria—an indication that surface water was getting into the water supply. The lab notified the MOE on five separate occasions. The MOE in turn phoned the WPUC, was assured the problems were being fixed, and let it go at that. The MOE failed to inform the medical officer of health, as by law it was required to do.

Looking at the role of this hierarchical level in the Ontario water quality control system provides greater understanding of the reasons for the Walkerton accident and suggests more corrective actions that might be taken to prevent future accidents. But examining the control flaws at this level is not enough to understand completely the actions or lack of actions of the MOE. A larger view of the provincial government role in the tragedy is necessary.

C.7 Provincial Government

The last component in the Ontario water quality control structure is the provincial government. Figure C.6 summarizes its role in the accident.

All of the weaknesses in the water system operations at Walkerton (and other municipalities) might have been mitigated if the source of contamination of the water had been controlled. A weakness in the basic Ontario water control structure was the lack of a government watershed and land use policy for agricultural activities that can impact drinking water sources. In fact, at a meeting of the Walkerton town council in November 1978 (when Well 5 was constructed), MOE representatives suggested land use controls for the area around Well 5, but the municipality did not have the legal means to enforce such land use regulations because the government of Ontario had not provided the legal basis for such controls.

Provincial Government

Safety Requirements and Constraints:

- Establish regulatory bodies and codes of responsibilities, authority, and accountability for the province.
- Provide adequate resources to regulatory bodies to carry out their responsibilities.
- Provide oversight and feedback loops to ensure that provincial regulatory bodies are doing their jobs adequately.
- Ensure adequate risk assessment is conducted and effective risk management plan is in place.
- Enact legislation to protect water quality.

Context in Which Decisions Made:

- Antiregulatory culture.
- Efforts to reduce red tape.

Inadequate Control Actions:

- No risk assessment or risk management plan created to determine extent of known risks, whether risks should be assumed, and if assumed, whether they could be managed.
- Privatized laboratory testing of drinking water without requiring labs to notify MOE and health authorities of adverse test results (privatizing without establishing adequate governmental oversight).
- Relied on guidelines rather than legally enforceable regulations.
- No regulatory requirements for agricultural activities that create impacts on drinking water sources.
- Spreading of manure exempted from EPA requirements for Certificates of Approval.
- Water Sewage Services Improvement Act ended provincial Drinking Water Surveillance program.
- No accreditation of water testing labs (no criteria established to govern quality of testing personnel, no provisions for licensing, inspection, or auditing by government).
- Disbanded ACES.
- Ignored warnings about deteriorating water quality.
- No law to legislate requirements for drinking water standards, reporting requirements, and infrastructure funding.
- Environmental controls systematically removed or negated.

Feedback:

- No monitoring or feedback channels established to evaluate impact of changes.

Figure C.6

The role of the provincial government in the accident.

At the same time as the increase in factory farms was overwhelming the ability of the natural filtration process to prevent the contamination of the local water systems, the spreading of manure had been granted a long-standing exemption from EPA requirements. Annual reports of the Environment Commissioner of Ontario for the four years before the Walkerton accident included recommendations that the government create a groundwater strategy. A Health Canada study stated that the cattle counties of southwestern Ontario, where Walkerton is located, are high-risk areas for *E. coli* infections. The report pointed out the direct link between cattle density and *E. coli* infection, and showed that 32 percent of the wells in rural Ontario showed fecal contamination. Dr. Murray McQuigge, the medical officer of health for the BGOS health unit (and the man who handled the Walkerton *E. coli* outbreak) warned in a memo to local authorities that “poor nutrient management on farms is leading to a degradation of the quality of ground water, streams, and lakes.” Nothing was done in response.

With the election of a conservative provincial government in 1995, a bias against environmental regulation and red tape led to the elimination of many of the government controls over drinking water quality. A Red Tape Commission was established by the provincial government to minimize reporting and other requirements on government and private industry. At the same time, the government disbanded groups like the Advisory Committee on Environmental Standards (ACES), which reviewed ministry standards, including those related to water quality. At the time of the Walkerton contamination, there was no opportunity for stakeholder or public review of the Ontario clean water controls.

Budget and staff reductions by the conservative government took a major toll on environmental programs and agencies (although budget reductions had started before the election of the new provincial government). The MOE budget was reduced by 42 percent and 900 of the 2,400 staff responsible for monitoring, testing, inspection, and enforcement of environmental regulations were laid off. The official Walkerton inquiry report concludes that the reductions were not based on an assessment of the requirements to carry out the MOE’s statutory requirements, or on any risk assessment of the potential impact on the environment or, in particular, on water quality. After the reductions, the provincial ombudsman issued a report saying that cutbacks had been so damaging that the government was no longer capable of providing the services that it was mandated to provide. The report was ignored.

In 1996, the Water Sewage Services Improvement Act was passed, which shut down the government water testing laboratories, downloaded control of provincially owned water and sewage plants to the municipalities, eliminated funding for municipal water utilities, and ended the provincial Drinking Water Surveillance Program, under which the MOE had monitored drinking water across the province.

The provincial water quality guidelines directed testing labs to report any indications of unsafe water quality to the MOE and to the local medical officer of health. The latter would then decide whether to issue a boil water advisory. When government labs conducted all of the routine drinking water tests for municipal water systems throughout the province, it was acceptable to keep the notification protocol in the form of a guideline rather than a legally enforceable law or regulation. However, the privatization of water testing and the exit of government labs from this duty in 1996 made the use of guidelines ineffective in ensuring necessary reporting would occur. At the time, the government did not regulate private environmental labs. No criteria were established to govern the quality of testing or the qualifications or experience of private lab personnel, and no provisions were made for licensing, inspection, or auditing of private labs by the government. In addition, the government did not implement any program to monitor the effect of privatization on the notification procedures followed whenever adverse test results were found.

In 1997, the MOH took the unusual step of writing to the Minister of the Environment requesting that legislation be amended to ensure that the proper authorities would be notified of adverse water test results. The Minister of the Environment declined to propose legislation, indicating that the Provincial water quality guidelines dealt with the issue. On several occasions, officials in the MOH and the MOE expressed concerns about failures to report adverse test results to local Medical Officers of Health in accordance with the protocol. But the anti-regulatory culture and the existence of the Red Tape Commission discouraged any proposals to make notification legally binding on the operators or municipal water systems and private labs.

A final important change in the safety control structure involved the drinking water surveillance program in which the MOE monitored drinking water across the province. In 1996, the provincial government dropped *E. coli* testing from its Drinking Water Surveillance Program. The next year, the program was shut down entirely. At the same time, the provincial government directed MOE staff not to enforce dozens of environmental laws and regulations still on the books. Farm operators, in particular, were to be treated with understanding if they were discovered to be in violation of livestock and wastewater regulations. By June 1998, the Walkerton town council was concerned enough about the situation to send a letter directly to Premier Mike Harris appealing for the province to resume testing of municipal water. There was no reply.

MOE officials warned the government that closing the water-testing program would endanger public health. Their concerns were dismissed. In 1997, senior MOE officials drafted another memo that the government *did* heed [55]. This memo warned that cutbacks had impaired the ministry's ability to enforce environmental

regulations to the point that the MOE could be exposed to lawsuits for negligence if and when an environmental accident occurred. In response, the provincial government called a meeting of the ministry staff to discuss how to protect itself from liability, and it passed a bill (the Environmental Approvals Improvement Act) that, among other things, prohibited legal action against the government by anyone adversely affected by the Environment Minister's failure to apply environmental regulations and guidelines.

Many other groups warned senior government officials, ministers, and the Cabinet of the danger of what it was doing, such as reducing inspections and not making the notification guidelines into regulations. The warnings were ignored. Environmental groups prepared briefs. The Provincial Auditor, in his annual reports, criticized the MOE for deficient monitoring of groundwater resources and for failing to audit small water plants across the province. The International Joint Commission expressed its concerns about Ontario's neglect of water quality issues, and the Environmental Commissioner of Ontario warned that the government was compromising environmental protection, pointing specifically to the testing of drinking water as an area of concern.

In January 2000, three months before the Walkerton accident, staff at the MOE's Water Policy Branch submitted a report to the provincial government, warning, "Not monitoring drinking water quality is a serious concern for the Ministry in view of its mandate to protect public health." The report stated that a number of smaller municipalities were not up to the job of monitoring the quality of their drinking water. It further warned that because of the privatization of the testing labs, there was no longer a mechanism to ensure that the MOE and the local medical officer of health were informed if problems were detected in local water systems. The provincial government ignored the report.

The warnings were not limited to groups or individuals. Many adverse water quality reports had been received from Walkerton between 1995 and 1998. During the mid- to late 1990s, there were clear indications that the water quality was deteriorating. In 1996, for example, hundreds of people in Collingswood, a town near Walkerton, became ill after cryptosporidium (a parasite linked to animal feces) contaminated the drinking water. Nobody died, but it should have acted as a warning that the water safety control structure had degraded.

The Walkerton inquiry report notes that the decisions to remove the water safety controls in Ontario or to reduce their enforcement were taken without an assessment of the risks or the preparation of a risk-management plan. The report says there was evidence that those at the most senior levels of government who were responsible for the decisions considered the risks to be manageable, but there was no evidence that the specific risks were properly assessed or addressed.

Up to this point, the Walkerton accident has been viewed in terms of inadequate control and enforcement of safety constraints. But systems are not static. The next section describes the dynamic aspects of the accident.

C.8 The Structural Dynamics

Most hazard analysis and other safety-engineering techniques treat systems and their environments as a static design. But systems are never static: They are continually adapting and changing to achieve their ends and to react to changes within themselves, in their goals, and in their environment. The original design must not only enforce appropriate constraints on behavior to ensure safe operation, but it must continue to operate safely as changes and adaptations occur over time. Accidents in a systems-theoretic framework are viewed as the result of flawed processes and control structures that evolve over time.

The public water safety control structure in Ontario started out with some weaknesses, which were mitigated by the presence of other controls. In some cases, the control over hazards was improved over time, for example, by the introduction of operator certification requirements and by requirements added in 1994 for continuous monitoring of chlorine residuals and turbidity in wells directly influenced by surface water. While these improvements were helpful for new wells, the lack of a policy to apply them to the existing wells and existing operators left serious weaknesses in the overall public health structure.

At the same time, other actions, such as the reduction in inspections and the elimination of the surveillance program reduced the feedback to the MOE and the MOH about the state of the system components. The water-testing laboratory privatization by itself did not degrade safety; it was the way the privatization was implemented, that is, without mandatory requirements for the private testing labs to inform the government agencies about adverse test results and without informing the private labs about the guidelines for this notification. Without regulations or oversight or enforcement of safe operating conditions, and with inadequate mental models of the safety requirements, operating practices have a tendency to change over time in order to optimize a variety of goals that conflict with safety, in this case, cutting budgets, reducing government, and reducing red tape.

An example of asynchronous evolution of the control structure is the assumption by the municipal government (mayor and city council) that appropriate oversight of the public water system operations was being done by the WPUC commissioners. This assumption was true for the early operations. But the elected commissioners over time became more interested in budgets and less expert in water system operation until they were not able to provide the necessary oversight. The municipal government, not understanding the changes, did not make an appropriate response.

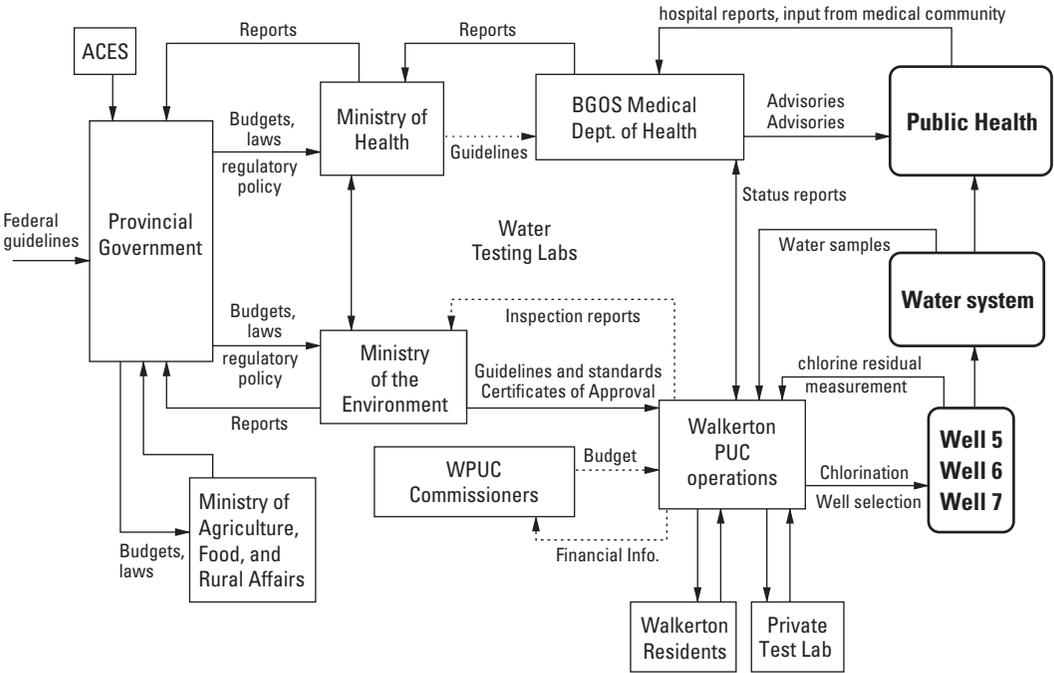
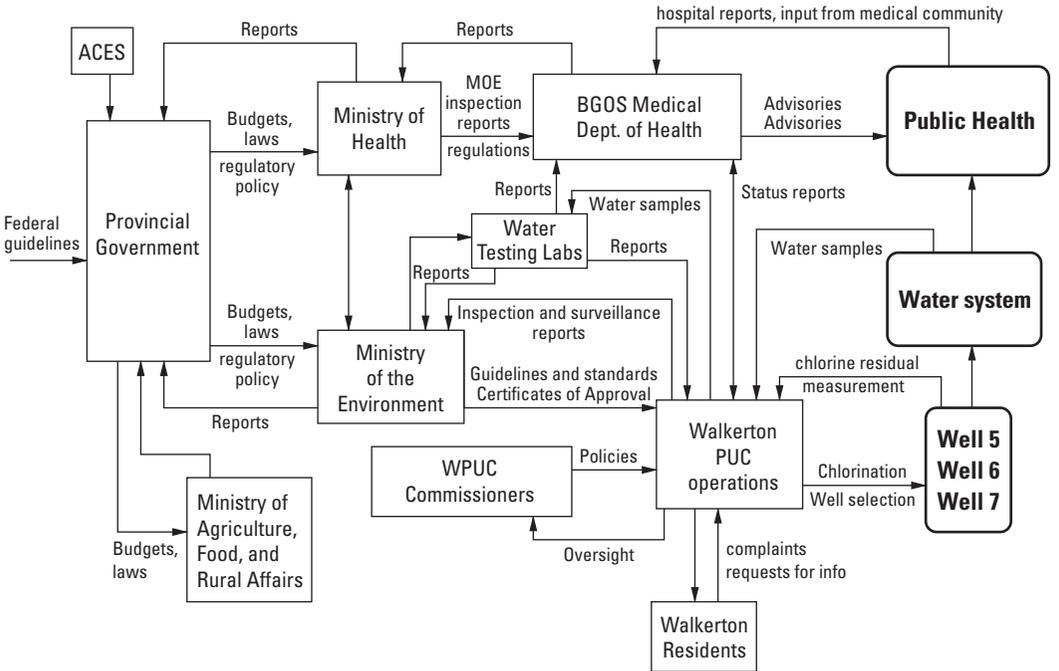


Figure C.7

The theoretical water safety control structure (top) and the structure existing at the time of the accident (bottom). Note the elimination of many feedback loops.

Changes may also involve the safety control structure environment. The lack of a provincial watershed protection plan was compensated for by the MOE ensuring that the water systems could not be affected by such runoff. The original Walkerton design satisfied this safety constraint. But factory farms and farming operations increased dramatically and the production of animal waste overwhelmed the existing design safeguards. The environment had changed, but the existing controls were not revisited to determine whether they were still adequate.

All of these changes in the Ontario water safety control structure over time led to the modified control structure shown in figure C.7. Dotted lines represent communication, control or feedback channels that still existed but had become ineffective. One thing to notice in comparing the original structure at the top and the one at the bottom is the disappearance of many of the feedback loops.

C.9 Addendum to the Walkerton Accident Analysis

Government representatives argued during the investigation that the accident cause was simply the actions of the Koebel brothers and that government actions or inactions were irrelevant. The Walkerton inquiry report rejected this viewpoint. Instead, the report included recommendations to establish regulatory requirements for agricultural activities with potential impacts on drinking water sources, updating of standards and technology, improving current practices in setting standards, establishing legally enforceable regulations rather than guidelines, requiring mandatory training for all water system operators and requiring grandfathered operators to pass certification examinations within two years, developing a curriculum for operator training and mandatory training requirements specifically emphasizing water quality and safety issues, adopting a province-wide drinking water policy and a Safe Drinking Water Act, strictly enforcing drinking water regulations, and committing sufficient resources (financial and otherwise) to enable the MOE to play their role effectively. By 2003, most of these recommendations had not been implemented, but three years after the accident, the Koebel brothers were arrested for their part in the events. Water contamination incidents continued to occur in small towns in Ontario.