CANADIAN WATER NETWORK
RÉSEAU CANADIEN DE L'EAU

Why Learn the Hard Way?

Experience from Waterborne Outbreaks

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Thoughts to Ponder

- What you get out of this lecture will depend on how you listen to the case studies described
- The premise is that once you have experienced something, you will see the world differently, (e.g., the new car example)
- Case studies are a way to learn from someone else's pain
- Learning is not automatic, you must try to put yourself in the situation and picture what was happening on the ground as if you were there.

What is Safe Drinking Water?

- The oldest "Safe Drinking Water Act" (U.S., 1974) does not define safe drinking water
- The Ontario Safe Drinking Water Act does not define safe drinking water
- The Canadian Guidelines for Drinking Water Quality do not define safe drinking water
- The WHO Guidelines for Drinking-water Quality, 3rd edition, define safe drinking water as water that "*does not represent any significant risk to health over a lifetime of consumption*….", i.e., water meeting WHO guidelines

What is Safe Drinking Water?

- Is safe drinking water assured by just meeting the water quality guideline numbers?
- How is that assurance provided?
- Lack of an explicit definition does not address public expectations of safety
- The Part 2 Walkerton Inquiry Report expressed the goal: "*to ensure that Ontario's drinking water systems deliver water with a level of risk so negligible that a reasonable and informed person would feel safe drinking the water*."

What is Safe Drinking Water?

- The foregoing approaches to safety require reduction of health risk to "*negligible*" levels and keeping consumers informed and confident
- Safety does not demand ZERO risk
- Safe may be difficult to define but an outbreak is clearly "***unsafe***"
- Assuring negligible risk of outbreaks or other adverse health outcomes requires a multiple barrier approach
- **There are multiple concepts of what is a multiple barrier approach**

Multiple Barriers to Assure Safety

- The Walkerton Inquiry outlined 5 key elements to provide a multiple barrier approach to assure safe drinking water:
  1. Source protection
  2. Effective treatment
  3. Secure distribution
  4. Effective monitoring
  5. Effective responses to adverse signals
- Failure in one “barrier” alone should not lead to an outbreak (a key rationale for MBA)
- But, assuring a “safe” water supply (i.e. negligible risk) requires ALL barriers to be functional

Multiple Barriers to Assure Safety

- Implementing a multiple barrier approach requires a comprehensive understanding of your system:
  - Nature of all major threats to system safety
  - Capabilities of the barriers
  - What monitoring signals mean or do not mean
  - What response actions are able to achieve and which are appropriate
  - Knowing when you do not know enough and when to call for help
- All require a sound, fundamental understanding of water quality

Case Study Introduction & Walkerton Overview

What to Listen For?

As you listen to the case studies that follow, ask yourself:

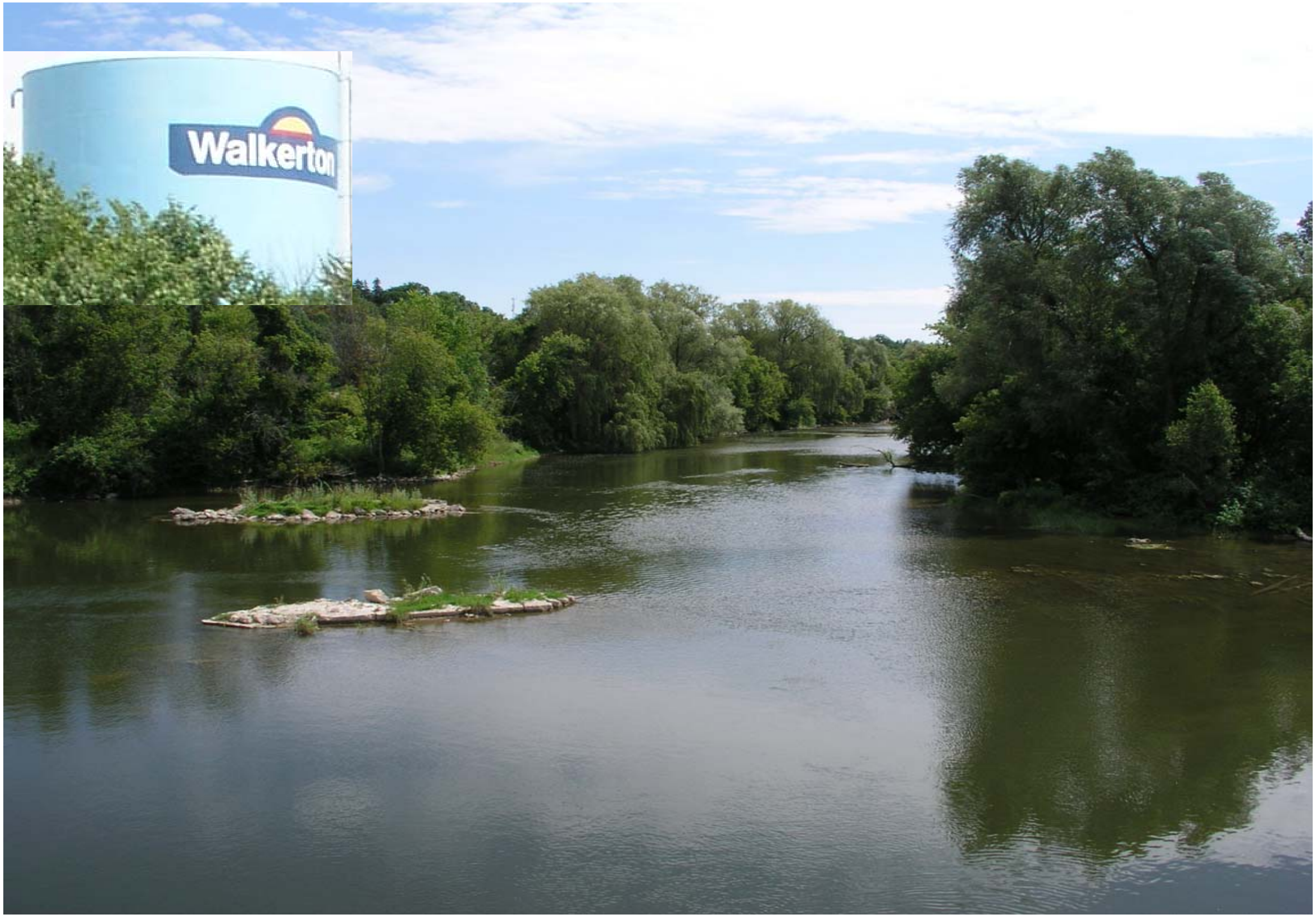
- Could this have happened to your system?
- Would all of the failures which occurred have been detected by your system management?
- Would your system have responded appropriately to all of the signals if they were detected?

How does drinking water become unsafe?

Each outbreak has its own unique features, but there are many factors in common:

- **Complacency** is a common factor
- Failure to understand the system thoroughly from source to consumer
- Failure to recognize the warning signs
  - Operational (unusual conditions)
  - External (weather, raw water quality, etc.)
- Failure to respond effectively to changes or seek help

May 2000 Walkerton, Ontario



Durham Street (main street) Walkerton


Well #5
Spring 2000 was a nice spring, nothing remarkable


May 8 – 12, a week of unusually heavy rain
5.3 inches over the week, 2.8 inches May 12 (a 1 in 60 yr storm)


Heavy flooding followed
Photo by George & Susan Magwood, Walkerton

After the rains, things seemed to return to normal

An Outbreak Emerges

- Widespread illness emerged on May 18, ~20 children absent from school & 2 children admitted to hospital with bloody diarrhea
- On May 19 a GI outbreak was evident in a retirement home, the Walkerton Hospital was overwhelmed with sick people
- An investigation was launched by the local health unit suspecting a foodborne outbreak
- Walkerton Hospital could not cope with the number of severely ill patients
- Air ambulance services were needed to transport patients to London ~170 km away

7 died from this outbreak

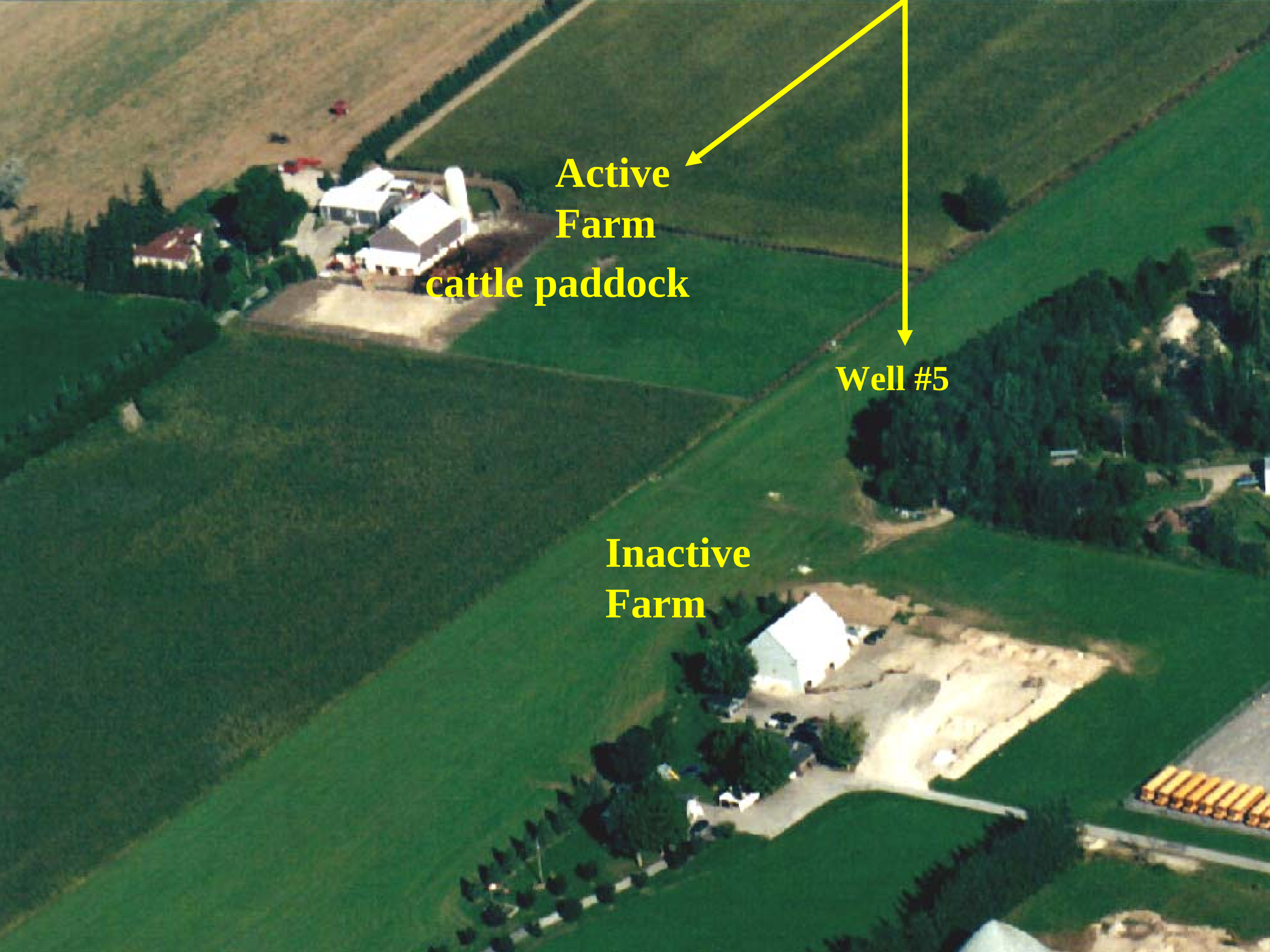
- A 2.5 year infant whose Mother had brought her from a nearby town to Walkerton for Mothers Day and she drank only 1 glass of water
- An estimated 2,300 individuals were ill with gastroenteritis (half the town’s population)
- 65 cases were hospitalized
- 27 cases developed haemolytic uremic syndrome (HUS) with potential for chronic kidney damage
- 52 % of HUS cases were between 1 and 4 yrs

Direct Causes of the Outbreak

- Many potential causes were identified
  - Water main construction
  - Fire events
  - Main breaks and repairs
  - Contamination of treated water storage
  - Cross connections
  - Flooding and human sewage contamination of wells
  - Surface water contamination of Well #6
- Most consistent and convincing evidence was for cattle manure contamination of Well #5, on or about Friday May 12

Direct Causes of the Outbreak

- Well 5 was commissioned in 1978 and was identified as contaminated during the initial pump testing
- Raw water monitoring over the years showed fecal coliform contamination of Well 5
- Occasional high (up to 3.5 NTU) turbidity readings occurred in raw groundwater
- Post-outbreak investigation showed that when the Well 5 pump was turned on, water levels on adjacent surface ponds dropped, confirmed by tracer studies
- Despite early warnings, there were no regulatory inspections during the 1980s


Active
Farm
cattle paddock
Well #5
Inactive
Farm

Direct Causes of the Outbreak

- Evidence of Well #5 does not explain why chlorine disinfection failed
- Water was supposed to maintain a chlorine residual of 0.5 mg/L for 15 min. This would have provided a CT of 7.5 mg/L-min
- This CT was
  - 150 times a published CT required for 99% (2-log) inactivation of *E. coli* O157:H7
  - 80 times a published CT for 99.99% (4-log) inactivation of *E. coli*

Direct Causes of the Outbreak

- Recalculation of the chlorine dosage based on evidence at the Inquiry suggested that chlorine was **dosed** at less than 0.5 mg/L
- The chlorine demand of manure washed into Well 5 likely destroyed any chlorine residual, eliminating any disinfection
- Measuring chlorine residual (was supposed to be done daily) should have revealed the problem in the first 24 hours
- Continuous chlorine residual monitoring with an automatic shutoff alarm would have revealed the problem immediately

Summary Analysis of Failures

1. Source Water Protection

- Well #5 was known to be contaminated with fecal coliforms from the time of commissioning 22 years before the outbreak
- The hydrogeologist who commissioned the well recommended that the Town establish a wellhead protection zone but no action was ever taken
- Heavy rainfall is a recurring factor in many outbreaks and should always be a signal for extra vigilance over potential source water contamination
- Geology of Well #5 made it highly vulnerable to surface contamination and obvious indicators of this vulnerability were ignored by all

Summary Analysis of Failures

2. Treatment

- Original recommendation for Well #5 called for chlorination
- A requirement to maintain a chlorine residual of 0.5 mg/L for 15 minutes was not being confirmed
- Chlorine **dosing** was inconsistent and less than 0.5 mg/L
- Well #7 had been operated without chlorination following May 12, misleading General Manager to believe that this might have been the problem

Summary Analysis of Failures

3. Distribution & Storage

- Several distribution and storage vulnerabilities were investigated, each of which could have contributed to an outbreak **if** Well #5 had not been the cause

4. Monitoring

- Daily monitoring of chlorine residual was not done or was done improperly
- Records of chlorine residual measurements were routinely recorded daily as 0.5 or 0.75 mg/L
- Inspector measures of chlorine residual were consistently less than 0.5 mg/L
- Most importantly, no chlorine residuals were measured during the outbreak – missed opportunity!

Summary Analysis of Failures

5. Response

- Operators and General Manager at Walkerton were qualified by experience to deliver water quantity, but none understood the critical importance of disinfection
- They continued to drink the water during the outbreak
- Operators testified that they kept chlorine low because of consumer complaints about chlorine taste
- General Manager assured the health unit that the water was “OK” on May 19, 2 days after receiving faxed adverse micro results for distribution system samples
- He began flushing mains and super-chlorinating after fixing chlorinator on Well #7 and he told health unit on May 20 that there was chlorine in the system

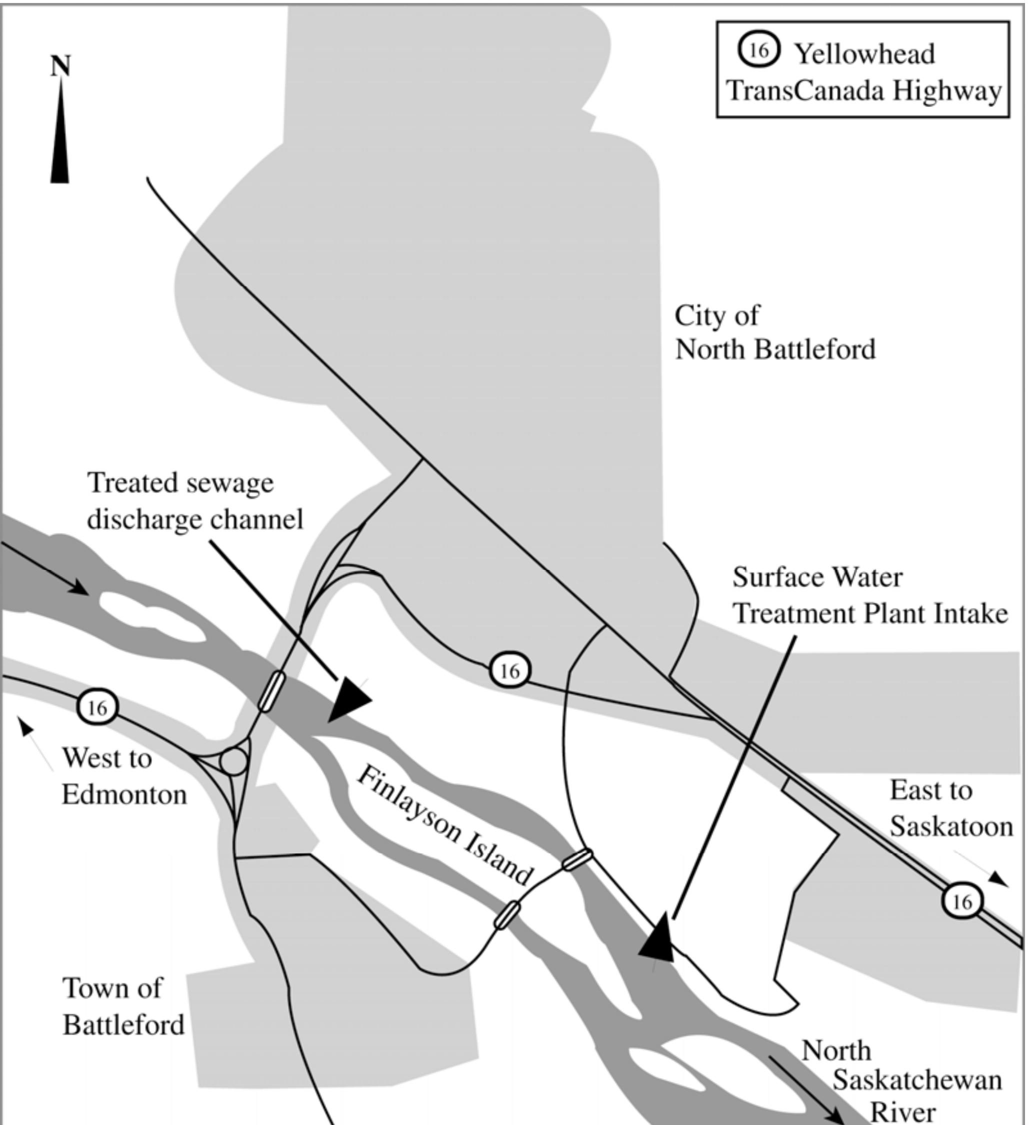
North Battleford, Saskatchewan

March – April 2001

North Battleford, Saskatchewan March / April 2001

- Only 11 months after Walkerton, despite unprecedented publicity across Canada in 2000 and 2001, North Battleford had an outbreak from *Cryptosporidium* infecting > 6000 consumers
- Contamination arose from the city's municipal sewage contaminating drinking water intake
- North Battleford refused to fix the sewage discharge problem despite several warnings
- No follow-up by any responsible authority

North Battleford Water System



- The source water is the N. Saskatchewan River, a source known to carry high levels of *Crypto* in spring from thawing of winter buildup of manure from cattle operations
- The water intake was ~3.5km downstream from the City's sewage outfall


North Battleford, SK
sewage outfall
North Saskatchewan River
drinking water intake

Direct Causes of the Outbreak

- March 1993, the **intake** had fecal coliform levels of 150,000 per 100 mL
- April 25, 2001,monitoring of raw river water at the drinking water intake: 120 oocysts per **100 L**
- May 2001, monitoring of the sewage effluent found 12,000 oocysts **per L**
- The water treatment plant relied strictly on chlorination for disinfection, so it was ineffective for *Cryptosporidium*
- Filtration (fine particle removal) **was** the only potential safety barrier

Direct Causes of the Outbreak

- The operations supervisor retired early in December 2000, after earlier taking stress leave expressing frustration at being unable to convince City management to invest in upgrades
- A crack in the concrete floor of the solids contact unit (SCU) clarifier was noted
- Repair was performed on March 20 in 1 day
- Past practice to retain coagulant sludge to restart the SCU was **not** done in March 2001

Direct Causes of the Outbreak

- The low turbidity raw water & the lack of seeding floc sludge made it difficult to re-establish an effective floc blanket in the SCU
- The operators did not regard the river source as a risk for *Cryptosporidium* or *Giardia* in winter while turbidity was low
- Did not recognize the risk of having the sewage outfall only 3.5 km upstream
- Operators assessed SCU performance based on settling of the floc blanket according to a home-made “test”

North Battleford Inquiry Findings

Inquiry Commissioner concluded:

"*There was a systematic failure on the part of the City of North Battleford to recognize its responsibility to produce safe drinking water.*

This failure was brought about by the City's collective lack of knowledge on what it takes to produce safe drinking water, and

***policies that discouraged the possibility that it might acquire such knowledge*.**"

http://www.justice.gov.sk.ca/nbwater/ can download report as a pdf

Summary Analysis of Failures

1. Source Water Protection

- Saskatchewan had no watershed protection program
- Poor sewage treatment practice at North Battleford had persisted for many years with warnings to 1963
- Evidence of impact on raw water quality at the intake (fecal coliforms of 150,000 per 100 mL in 1993) led to warnings to the City, but no effective action was taken
- Even after the outbreak and its evident connection with the City's sewage outfall, the City continued to dispute this sewage influence at the Inquiry

Summary Analysis of Failures

2. Treatment

- Reliance on chlorination as sole disinfectant was not adequate for a raw water source that was obviously vulnerable to *Cryptosporidium*
- The timing and performance of maintenance on the SCU were both poor
- Tolerance of poor clarification prior to filtration for weeks was wrong for a high risk water source like this one
- Operators did not understand either the risks that their raw water source posed nor the limitations of their treatment system under these conditions
- Backwash water was recycled to the plant inlet, contrary to good filtration practice

Summary Analysis of Failures

3. Distribution & Storage

- No explicit failure risks were raised

4. Monitoring

- Operators did not perform jar tests to optimize coagulation performance; they relied only upon their settling performance test to judge the performance of coagulation and flocculation in the SCU
- The plant was not equipped to measure final turbidity from each individual filter so filters were brought back on-line after backwashing before they had properly ripened to assure good turbidity removal

Summary Analysis of Failures

5. Response

- After the early retirement of the operations supervisor in December 2000, the remaining operators lacked the experience / training to cope with the problems they encountered in March / April 2001
- The communications between public health personnel, the City operations personnel and the provincial regulator were not effective delaying outbreak identification and issuing of a boil water order

Did you know about?

- Cabool, Missouri, 1989/90

  243 confirmed cases of *E. coli* O157:H7, with 32 hospital admissions and **4 deaths** caused by high quality groundwater contaminated in **distribution**

- Gideon, Missouri, 1993

  650 cases, with 15 hospital admissions and **7 deaths** from salmonellosis caused by high quality groundwater contaminated in **distribution**

- Washington County, New York, 1999

  >3000 cases *E. coli* O157:H7, 71 hospitalized, 14 HUS, **2 deaths** caused by shallow groundwater contaminated by septic tank drainage

If Not, Why NOT?

That was then, this is now!

- Consider these outbreaks since 2002:
  - Bergen, Norway 2004 (4,000 – 6,000 *Giardia* cases)
  - Nokia, Finland 2007 (6,500 cases, mixed pathogens)
  - Northampton, England 2008 (422 cases, crypto)
  - Alamosa, Colorado 2008 (1 death, 1300 cases salmonella)
- These are not the only outbreaks which have occurred, but they all have features relevant to you

Bergen, Norway Case Study

Sep – Dec 2004

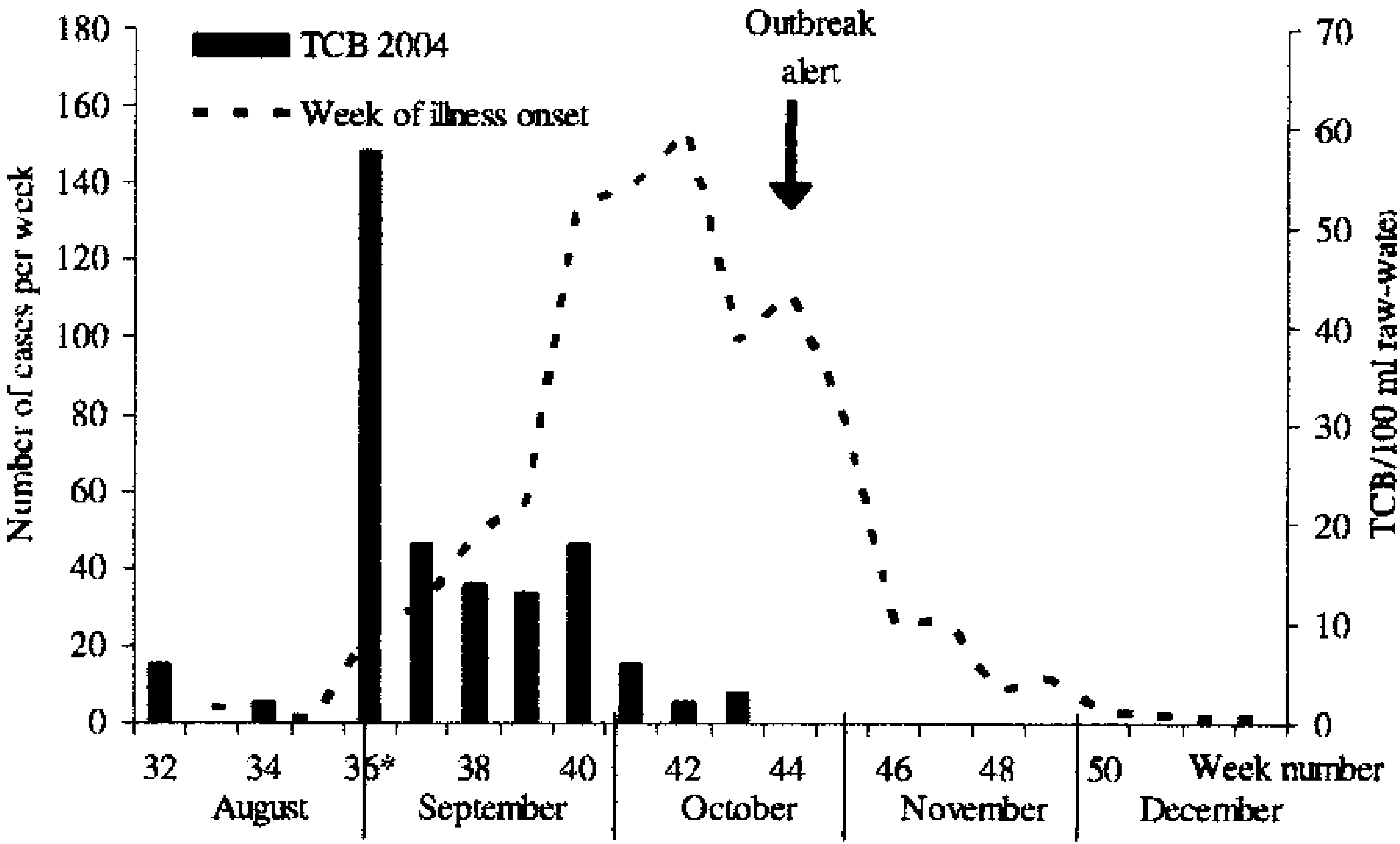
Scope of Outbreak

- Bergen, Norway a city of about 240,000 on Norway's west coast experienced Norway's first documented *Giardia* outbreak in late 2004 and early 2005
- Approximately 1,400 residents were diagnosed with giardiasis between August 2004 and January 2005
- Overall, 4,000 to 6,000 cases were estimated to have occurred in this outbreak among a population of ~43,000 served by the implicated supply

Water System

- Bergen is supplied by 6 different water sources
- Lake Svartediket is a lake supplying surface water to about 43,000 residents of central Bergen, in 2004 with only chlorination
- The waterworks was established in 1855 and it had no valid certificate of acceptance by the water approval authority
- Bergen is one of the wettest places on the planet, with rain ~300 days a year typically with over 2 m of annual rainfall

TCB = Thermo-tolerant coliform bacteria



Nygård et al. 2006

Direct Causes of Outbreak

- Giardiasis was viewed as a “foreign” disease attributed to travel abroad
- *Giardia* was not recognized as a threat to drinking water supplies in Norway
- The catchment area of Lake Svartediket was used for recreation, grazing of sheep and some residential dwellings were located close to water intakes (located at 12 to 17 m depth)
- No filtration, only chlorination was used for treatment, dosage (CT) not stated, but 1 – 2 km of pipeline not likely to provide long contact time

Direct Causes of Outbreak

- Raw water reached 64 *E. coli* / 100mL on August 31, but such levels were regarded as common for that time of year
- Treated water met regulatory requirements except for 1-2 *E. coli* /100 mL on 14 Sept when chlorinator failed over night. Returned to zero when chlorination resumed
- **Turbidity remained < 1 NTU**
- Maximum *Giardia* cysts found were 1 cyst / 10 L in treated water (28 Sept) and 5 cyst / 10 L in raw water in November

Summary Analysis of Failures

1. Source Water Protection

- ❖ The source water had been used for 150 years without evident problems
- ❖ No consideration of source water contamination was given
- ❖ Residential sewage systems nearby intake were in disrepair

2. Treatment

- ❖ Surface water supply was treated with only chlorination, no filtration despite ample experience that protozoan pathogens need filtration

Summary Analysis of Failures

3. **Distribution & Storage**
   - There was no mention of any thought about chlorine contact time
4. **Monitoring**
   - Raw and treated water were monitored for *E. coli* and treated water monitoring for *Clostridium* gave some indication of *Giardia* concern, but it was ignored
5. **Response**
   - Norway did not see itself at risk from *Giardia*
   - Failed to recognize that international travelers bringing *Giardia* to Norway inevitably made Norway vulnerable to outbreaks of giardiasis

Alamosa, Colorado Case Study

5 March – 11 April 2008

Scope of Outbreak

- The City of Alamosa with a population of about 9,000 is located in south central Colorado about 370 km south of Denver
- In March and April 2008 an outbreak of salmonellosis caused 442 reported illnesses, with 122 laboratory-confirmed, and one death (54 year old male)
- Epidemiogical estimates suggest that up to 1,300 people may have been ill

Alamosa Water System

- Alamosa's community public water system consisted of 7 deep artesian wells, 2 elevated storage tanks, 1 ground-level storage reservoir, and approximately 80 km of distribution line
- Water from the wells was not chlorinated prior to distribution
- Alamosa had operated under a waiver from disinfection from the State chlorination requirement since 1974
- Alamosa had generally met regulatory requirements except for occasional coliform violations

Direct Causes of Outbreak

- One of three water storage tanks, the Weber reservoir was clearly in poor condition, with cracking and noticeable holes in the corners of the concrete structure.
- There was significant sediment in the bottom of the tank, 30 to 45 cm deep by some estimates
- Staff had no records or memory of the last time the tank had been disinfected.
- The city later reported that the reservoir was last drained and cleaned out in 1984.

The Weber Reservoir was clearly vulnerable

The Weber reservoir was clearly vulnerable

Summary Analysis of Failures

1. **Source Water Protection**

❖ The deep confined aquifer groundwater source was not directly implicated. In this regard, the Alamosa outbreak was similar to previous fatal outbreaks in Gideon, Missouri (7 deaths, *Salmonella*, 1993) and Cabool, Missouri (4 deaths, *E. coli*, 1989/90)

2. **Treatment**

❖ The groundwater was distributed without chlorination, again similar with previous fatal outbreaks at Gideon and Cabool

Summary Analysis of Failures

3. Distribution & Storage

- Contamination evidently occurred in storage, again similar to the fatal Gideon outbreak in 1993
- The flaws in the Weber reservoir were known, but not acted upon

4. Monitoring

- There was no chlorine residual to monitor
- Oddly, total coliforms were used rather than *E. coli*
- This system, without treatment, appeared to have little focus on water quality, which was apparently taken for granted

Summary Analysis of Failures

5. Response

- ❖ The outbreak was detected only through excess illness occurrence
- ❖ The initial response, as in many others, was slow, but was eventually declared a State emergency
- ❖ There was excellent support from other utilities and agencies once the disaster was apparent
- ❖ The use of bottled water rather than a boil water order was linked to concerns about the elevated arsenic, particularly with system flushing and shock chlorination

Recurring themes

- Vulnerability can exist for a long time before conditions align to cause an outbreak
- Pathogens are an ever-present risk wherever humans, pets, livestock or wildlife reside, i.e. everywhere
- Treatment systems will fail intermittently
- Treatment systems do not deal well with sudden change
- Major treatment changes should not be implemented full scale without piloting

Recurring themes

- A common failure to learn from own mistakes, let alone learning from others
- Failure to value the critical role of operators and to invest in better training
- Operators need to know enough to recognize when they do not know enough and should ask for help
- Complacency occurs at many levels
- Managers / politicians have engaged in willful blindness about problems

What is a Competent Water Provider?

One that will:

- ♦ actively promote and reward informed vigilance
- ♦ promote and maintain understanding of the whole water system, its challenges and limitations
- ♦ adopt effective real time process control as a basic operating approach (maintaining chlorine residuals and low turbidity) in every way possible
- ♦ maintain fail-safe multiple barriers appropriate to the challenges facing the system

Do current regulations assure this?

If not, who can assure this?

Operators Preventing Outbreaks

- **Know your system**: capabilities of your barriers in relation to nature of the hazards
- Translate system knowledge into operational monitoring to detect imminent hazards
- Establish operational limits to trigger alarm
- Work with management to plan responses to abnormal conditions and use problem-solving as events unfold
- Recognize when you are in over your head and call for help

Operators Preventing Outbreaks

- Recognize vulnerabilities that demand improvement
- Take ownership of problems to ensure that managers **do know** about problems and cannot easily claim ignorance
- Document near failures for future learning
- Operator training needs to include learning from failure cases and experience with near failures
- We use simulation for training airline pilots
- Water operators are often responsible for the safety of more people

Those who cannot remember the past are condemned to repeat it.

— George Santayana

Walkerton Memorial Park

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