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# Constructing community health and safety

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**Access to a sufficient amount of safe water is taken for granted in industrialised nations. Yet, as multiple incidents of contaminated water supplies show, citizens of highly industrialised nations such as Canada may not have access to safe water—the deadly *E. coli* outbreak in Waterton, Ontario, being but the most visible among many. Municipal engineers may find themselves between enemy lines as they are asked to assess available data of very different, even incommensurable, types in an evaluation of alternative solutions of access to safe water. Such access also takes into account safety issues such as those concerning the environment and fire hazards. This article reports the results of a ten-year anthropological study of science and municipal engineering in the often-acrimonious conflict over access to the municipal watermain and safe water in one Canadian community. In the history of the conflict, municipal engineers repeatedly found themselves between a rock and a hard place, having to evaluate conflicting knowledge claims of qualitative and quantitative nature from quite different sources about the quantity and quality of water available to a part of the community zoned rural area. In considering solutions, the municipal engineers had to take into account often-conflicting constraints posed by the environment, economy and social justice. Several alternatives are proposed that allow the integration of quantitative and qualitative knowledge in decision making concerning the different safety issues linked to municipal water.**

## 1. INTRODUCTION

Over the last century, science, engineering and cultures have developed exponentially in terms of both knowledge resources available and the complexity of internal and external relations. Thus, over recent decades, social scientists have become interested in the relationships between scientists, engineers and society generally.[1] Research has shown that the general public not only takes an interest in science and engineering but also is beginning to contest the exclusive claims scientists and engineers make about what constitutes best knowledge and best practice when it comes to the difficult issues facing humanity today (e.g. climate, environment, genetics and human health). The public has begun to influence research and development through participation in public policy, economics and a large number of non-governmental organisations.[2] As a result, the already increasing complexity due to the exponential accumulation of not-always-unanimous scientific and technological knowledge and the exponential increase in the numbers of stakeholders that intend to make themselves heard increases even further. Studies of science or engineering now point out that problem definitions and solution frames are no longer in the hands of one type of expert but rather are entities that emerge unpredictably from the interaction of many social actors. The general finding is that in the real world, in contrast to the laboratory or design office, problems are never those of engineering (technology) alone. Interests, local noise and aesthetic sensitivities, environment, politics, health and many other factors mediate the decisions all engineers have to make, including the municipal engineers involved in the design of the ultimately abandoned, individualised rapid transit system (called Aramis) for several French municipalities.[3] In the case of Aramis, the constraints imposed by different actors (municipal governments, design engineers, residents, municipal engineers) and issues (health, safety, technical and social surveillance, convenience) all contributed to producing conditions that eventually made the project non-viable.

Over the past decade, several studies that required following research scientists, engineers and technicians from a variety of disciplines from their desks and laboratories into the world of social relations were conducted by the author.[4] In each case, it was noted that trouble and conflict often arise when science and engineering move into the real world, confronting people, communities, societies and their respective needs. Ideas that worked on paper in engineers' or scientists' offices no longer worked, did not scale up and, worse, often did not apply in the settings for which they were produced. For example, scientists who designed fish-hatching-related experiments found that what they were doing for the safe disinfection of salmon brood on small scales in laboratories turned out to be unworkable in the hatcheries; engineers who designed a microwave tower with a strong mobile phone signal found themselves embroiled in strong community opposition to the selected sites (including a local park) over health (effects of radiation on human health) and environmental concerns; and the designers and operators of wind farms in the ocean but within sight of the local community had to abandon the project because of strong popular resistance to the change in the aesthetic qualities of the region.

The purpose of this work is to provide an account and explication of the struggle over access to the watermain in Central Saanich, a municipality on Vancouver Island in the Pacific Ocean not far off the west coast of Canada. Municipal engineers were asked to write reports and summarise other reports for the purpose of informing the municipal council on whether to extend the existing watermain by 4 km to service 64 homes currently drawing their water from wells (many of which had shown, in some tests, high biological and chemical contaminant levels). The decisions to be made were not easy—there were not only conflicting scientific and engineering reports but also conflicting testimonial knowledge, interests, politics and ethical principles. This study therefore contributes to finding answers to questions such as

(*a*) What do you do, as a municipal engineer, if the information you receive for making decisions about safety issues is divergent, contradictory and of different epistemic quality and nature?
(*b*) How do you integrate different types of knowledge and information?

The account begins by commenting on the anthropological method used in the study. The background to the case study is described in section 3, the particulars of the case are covered in section 4, the acrimonious public debate is discussed in section 5 and section 6 examines how municipal engineers were caught up in the conflict. The paper concludes with recommendations for the integration of diverse forms of knowledge, facts (hard, soft), interests and obligations (safety, environment, justice).

## 2. METHOD

The methods of anthropologists are likely to be unfamiliar to engineers. To understand the relationship of engineering and engineers in society, a number of rules of method assist in constructing an account of relevant events without taking sides and without bias. Anthropologists have to be as undecided as the actors and should study all sides of controversies and look at two sides whenever boundaries are established.[5] When confronted with arguments about the irrationality of one or the other social actor, anthropologists study neither the rules of logic broken nor the societal structures, but investigate the displacements of actors and the networks built by these displacements.[6] Finally, before attributing special qualities to the minds of people, anthropologists follow the various ways in which documents are gathered, combined, tied together and sent around.

This study of the conflict around water is based on a large number of documents, including all newspaper articles, minutes of municipal and district meetings, all scientific and task force reports submitted to the municipal engineering department, 22 interviews with the major players and residents involved (including the mayor, chair of water and waste management committee), audio recordings of public meetings, records of the meetings and documents produced by the Water Advisory Task Force (WATF), well logs, scientific, medical and engineering reports, personal notes kept by a person working for the WATF chair, and minutes of the water and waste management committee. Analysis of such a large amount of information requires a rigorous approach in which multiple data pertaining to the same issues are triangulated, verified through additional information-seeking processes or presented as conflicting. The anthropological analyst withholds, to the extent humanly possible, his or her own opinions and predilections and presents the interpretations of the stakeholders rather than interpreting data on his or her own. The data are contextualised by further research data from a three-year study of water-related environmentalism and stewardship in the same community (the environmental group was started by some of the key players discussed later) and from a two-year study of scientific literacy of students whose science curriculum focused on the environmental health of the watershed that supplied the residents with the water in their wells.

## 3. BACKGROUND AND CONTEXT

The controversy over water at the core of this article took place in Central Saanich, a suburban community on the southern part of Vancouver Island. Central Saanich is one of 13 municipalities that constitute the Capital Regional District (CRD, often denoted by ‘Victoria’ (technically only one of the municipalities)). The municipality is situated on the northwest coast of the North American continent, usually associated with a lot of rain and sufficient water resources. However, water quantity has been and continues to be a major problem. There is insufficient rain to fill the reservoirs supplying the CRD so that nearly every summer water restrictions are in place. Most of the rain falls in October to March, but is insufficient to fill the aquifers because much of the water tends to be carried away by ditched and straightened creeks[7] and irrigation by local farms strains the existing water levels. All monitoring wells show substantial variation in water levels (Fig. 1). Changes related to urbanisation and the increase in impervious surfaces (pavements), loss of forest cover throughout the watershed and along the stream banks, loss of wetlands and recharge areas, and the loss of natural stream conditions further increase the pressure on the aquifers.

An integral part of the municipality is its strategic direction to ascertain ‘a safe, healthy community’, which in particular means

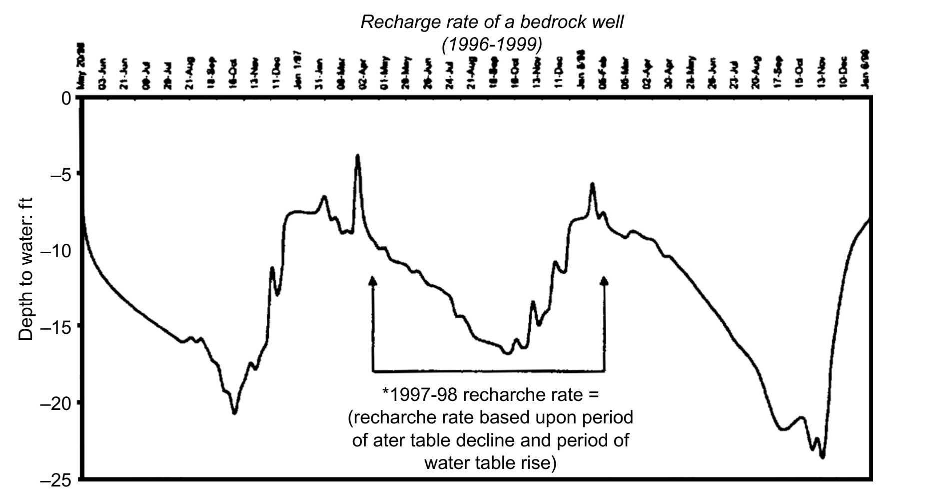


Fig. 1. Typical yearly groundwater variations, here shown for a three-year interval

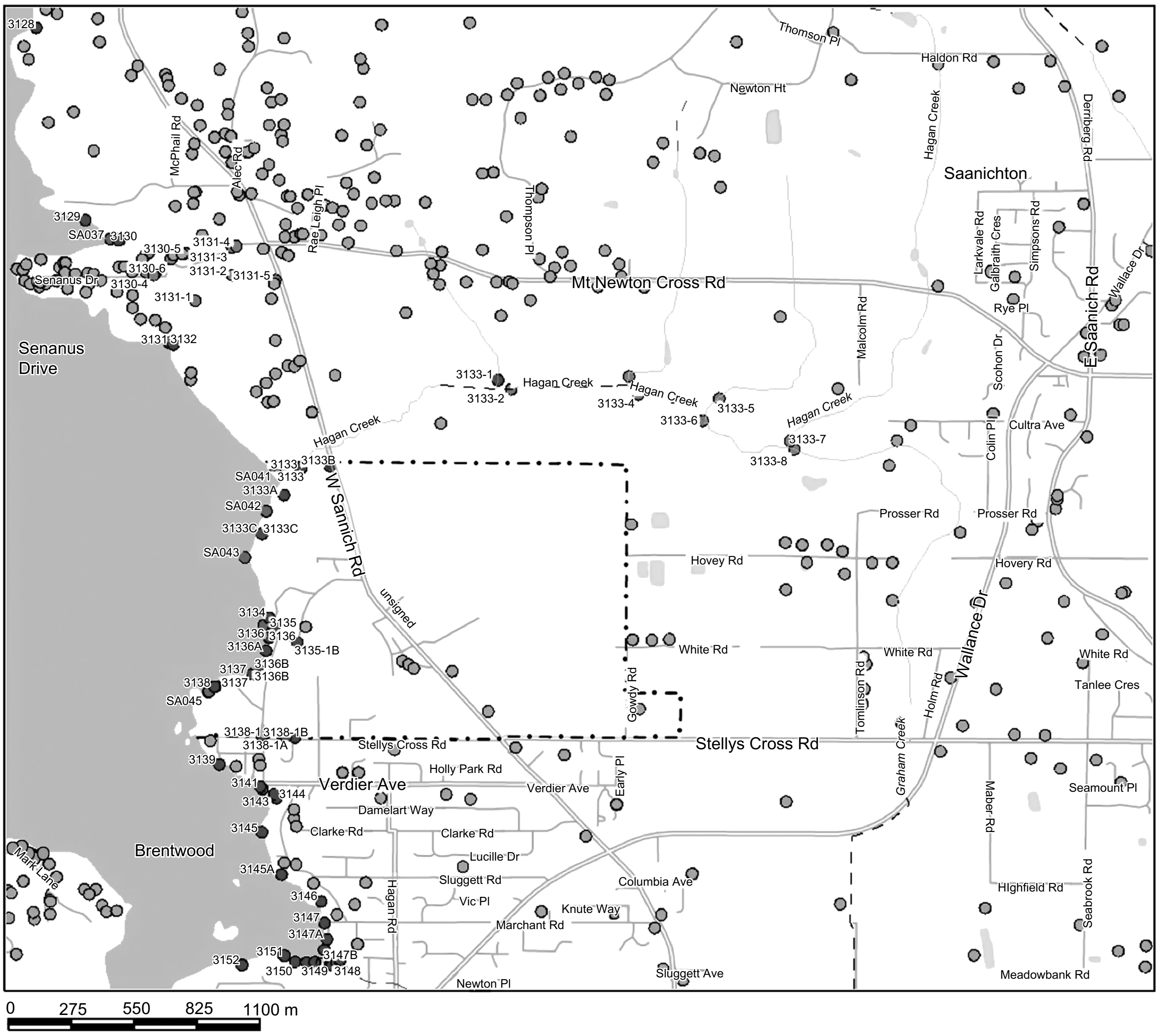


Fig. 2. Central Saanich and the location of Senanus Drive (upper left) and Mount Newton Cross Road

that it provides fire inspection, prevention and suppression programmes and services and enhanced quality of life. The municipality's Strategic Plan 2006 states there are 'environmentally sustainable options to refine and harmonise the District's policies for waterline extensions to un-serviced areas, enhanced standard of infrastructure, in particular, facilities (design and construction of… watermains'. The community formed the WATF as an appropriate mechanism for dealing with the pressing water problems. Its role was to make recommendations to council with respect to drainage, watershed health, water management and other environmental impacts related to water issues. The seven members of the WATF represent a diverse group of residents including the founders of an environmentalist group; all members lived in the area currently not connected to the watermain but were differentially affected.

In the late 1990s, local newspapers regularly carried features concerning the water at Senanus Drive (Fig. 2), a part of Central Saanich zoned 'rural estate' (RE-3). The RE-3 zoning requires a minimum lot area of 0·8 ha (2 acres) when on a community water system and a minimum of 2·0 ha (5 acres) if not. (Although Canada formally went metric in 1970, many aspects of public life are still handled in the imperial system. Thus, many of the reports studied included imperial rather than metric measures.) Much of the adjoining Mount Newton Valley has the status of agricultural land reserve. All the properties along Mount Newton Cross Road, on Senanus Drive and on the hillsides to the north take water supply from wells. The areas of higher agglomeration are Saanichton and Brentwood (also shown in Fig. 2). The nearest gas stations where residents collected water during periods of high water contamination levels in 20 l (5 gallon) containers (as photographically depicted in one newspaper article) are in Brentwood and Saanichton, meaning that residents had to drive 4–5 km each way to obtain drinking water.

Senanus Drive, the area involved in the controversy, lies in a wooded area on the coast, about 5 km away from Brentwood and Saanichton (Fig. 2). Together with Mount Newton Cross Road and Mount Newton Valley (with Hagan Creek and its tributaries as the water-carrying bodies), it constitutes an idyllic rural-zoned area of the Saanich Peninsula (Fig. 3). The valley bottom is taken up by farms, most of which now concentrate on producing hay that can be harvested, depending on the year, up to four or

Fig. 3. West end of Mount Newton Valley, which joints the Senanus Drive area (back, right)

five times. On the hillsides and along the wooded Senanus Drive, are private properties that range from medium to very high in terms of property value ($6·5 million). The road descends from a high point of 40 m elevation at its eastern end to 9 m at its western end. Geologically, the Senanus Drive area consists of a thin overburden layer (0–12 m) overlying bedrock, which is part of the island intrusion rock unit made up of granitic (fractured) rock types. The fractured granite is tapped by wells ranging from 20–165 m deep, yielding flow rates from 0·022 to 2·65 l/s.

Faecal coliform bacteria are a continued concern for both the wells and surficial water. For the period 1998–2005, values at one property—after taking out one apparent outlier (89 600 faecal coliform/100 ml)—showed a mean of 592 faecal coliform/100 ml with a standard deviation of 1065. The other outlet on the opposite (north) side of the Senanus Drive area showed a mean of 1196 faecal coliform/100 ml (SD 1706 faecal coliform/100 ml). The main creek in the area also has many areas with high coliform counts and repeated contaminant-related fish deaths were reported.

## 4. SENANUS DRIVE: ARE THERE REAL WATER PROBLEMS?

### 4.1. History of the problem

Some residents, having lived on Senanus Drive for 40 years, had detailed formal and informal testimonial knowledge about variations in water quantity (well logs at different periods) and quality (as assessed by hired engineers). The residents have individual wells that draw on the local aquifers. For years, local newspapers reported that in the summer months, the water in the Senanus Drive area was biologically and chemically contaminated, as measured, among others, by the Regional Health Board. Sometimes, residents were advised by the health board not to use or to boil their well water, with the result that many residents opted to obtain water from the gas stations in Brentwood or Saanichton. Besides concerns for human health, newspapers also highlighted the other impacts, including corrosion of appliances, storage tanks (Fig. 4), pumps, waterlines and damage to house and garden plants.

Anecdotal accounts were given of fires and accidents in which the absence of water augmented the damages incurred. Many of the storage facilities for fire-protection purposes appear makeshift. Some residents converted swimming pools into water-holding facilities (Fig. 5), some configured aesthetically pleasing fishponds for the same purposes and others used water fountains. During drought periods, however, much of the water evaporates and there is not enough water in the wells to supply homes, let alone to replenish the ponds. So, precisely during the periods that

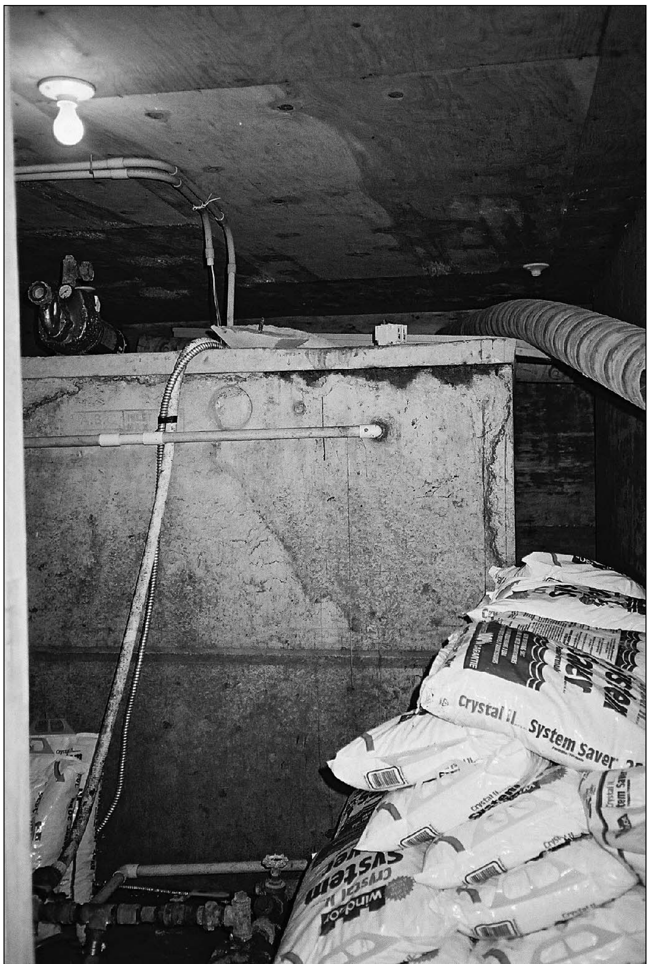


Fig. 4. Corroded water storage tank at one property

Fig. 5. An old swimming pool is used as a holding pond for fire-fighting purposes

forests and woodlands in the area are under the highest fire alerts, there is insufficient water to fight potential fires.

For 30 years, residents of Senanus Drive requested to be connected to the watermain that already supplied other residents of Central Saanich. The residents put the issue forward to the Saanich Peninsula Water Commission, which decided that the matter was a municipal concern. However, Central Saanich town councils and mayors blocked all demands, attempting to keep the watermain away from Senanus Drive to prevent the area from being developed, as one of the mayors told local newspapers while in office. Faced with an insufficient quantity of water that is, furthermore, of questionable quality, residents utilised a number of coping strategies—they had water delivered, drilled multiple wells, spread out their water usage, stored water in case of fire, chlorinated their water systems, regularly replaced corroded plumbing fixtures and attempted to alleviate problems by means of individual treatment systems.

#### 4.2. Reports on record

Individual families (through consultants they hired, e.g. Giles Environmental Engineering) and the Capital Health Region (CHR) had previously tested the water. Invariably, a variety of problems arose, including chemical and biological contaminants. However, the majority of the WATF—all of whom live(d) along the proposed watermain route but on Mount Newton Cross Road not affected by the water problems—decided that previous studies and testimonial evidence was insufficient or flawed. The WATF decided to hire yet another independent consultant firm, Lowen Hydrogeology Consulting. This firm regularly works for various municipalities in the areas, with special expertise in groundwater and the impact of effluents and sewage on water quality. The firm is used to controversy—some studies have been contradicted by the results of other studies, a fact that has led litigants in these cases to play conflicting scientific and engineering reports against each other.

Giles Environmental Engineering repeatedly measured elevated levels of chemical contaminants, but these results were not retained for discussion because the residents had hired the company. Giles concluded, among others, that many of the parameters that exceeded the 6th edition Guidelines for Canadian Drinking Water Quality (GCDWQ) were related to aesthetics but were in fact a health concern since the water could cause 'health problems due to avoidance of ingestion, reluctance of use for personal hygiene, malfunctioning of laundry and dish washing machines, and use of harmful chemicals for removal of stains and deposits'.

At the request of the residents, the Health Protection and Environmental Services branch of CHR, under the direction of its chief environmental health officer, repeatedly sampled wells along Senanus Drive (Fig. 6) to study the bacteriological and chemical quality of the water. The initial sampling regimes were followed up by further tests carried out by an environmental health officer and a regional public health engineer, both of whom had extensive experience in groundwater sampling and analysis. Initial testing was conducted on 18 September 1996, with follow up testing carried out on 11 April 1997, 3 December 1997 and 6 February 1998.

For several homes, the CHR report listed evidence of chemical element concentrations that exceeded the GCDWQ, including the presence of chromium, manganese and sodium. Bacteriological analyses showed elevated levels of heterotrophic plate counts (likely caused by the high chromium levels) and some wells with repeated measures of high coliform bacteria counts (535, Fig. 6). Finally, physical analysis showed that water hardness was high (1 well), very high (2 wells) or unacceptably high (4 wells) for seven of the eight wells sampled, all lying outside the 80–100 mg/l recommended by GCDWQ because they cause a bad taste and bitterness in the water. pH values of 8·03–8·72, which cause scale formation and decrease efficiency in chlorine disinfection methods, all lay near the top of or exceeded the recommended levels. To complete their studies, CHR staff also collected and reported 'anecdotal evidence' about well histories (quantity), water-hardness problems and water quality (bitterness). Its report included a photograph of manganese-caused dishwasher staining. The report concluded that the groundwater in the area should not be considered potable, is not palatable and should not be used for drinking water; residents should be advised to seek alternative sources of drinking water. The report suggested that the long-term solution, however, would lie in an extension of the watermain. During a meeting with the CRD, the medical health officer declared that if a currently healthy resident were required to go on a sodium-restricted diet,

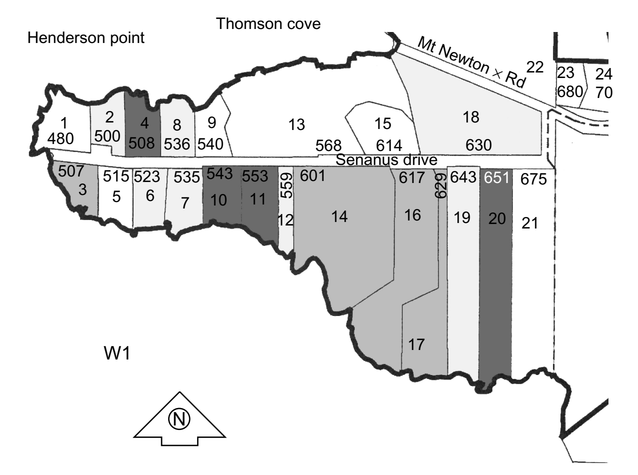


Fig. 6. Sampling locations of Capital Health Region (light grey), Lowen Hydrogeology Consulting (mid grey) and both (dark grey)

their well water would present a health risk; he also suggested that residents would be unable to sell their homes to people on such diets.

The municipal council retained Lowen Hydrogeology Consulting to provide an independent assessment. The company sampled seven 'representative' wells (Fig. 6) once (5 May 1997) and, based on this sampling episode, reported no biological contamination present and four samples exceeding the GCDWQ 'aesthetic objectives' for total dissolved solids, high levels of which 'can impart excessive hardness, unpleasant taste, mineral deposition, and corrosion'. Additional contaminant levels exceeding GCDWQ—for iron, manganese and zinc—affected a small number of wells. The report concluded that 'in-home water treatment systems should be investigated for any homes with well water that is corrosive, deposit forming or unpalatable'.

The CRD and Lowen reports were available to the WATF, charged with producing its own report—including the production of additional data—and solutions. Because the WATF could not come to a unanimous recommendation, two reports were filed with the municipal engineering department, referred to in subsequent discussions as the 'majority' and 'minority' reports. The majority report largely based its recommendations on the data provided by Lowen-recommended individual and local solutions (e.g. cisterns) but recognised the impact of environmental solutions, including measures that 'relieve pressures on groundwater supply'. The minority report grounded its assessment on two major pieces of information: the degree of the problem along Senanus Drive as apparent from testimonial evidence of residents and the lower-than-recommended water quantity available to two-thirds of families. It recommended the construction of a watermain extension from the eastern part of Mount Newton Cross Road already serviced to the western end of Senanus Drive.

In various media (local and regional papers) and situations (council meetings), residents provided ample testimony to back up the stresses they experienced as a result of the water situation. The issue, therefore, was not only one concerning safety relative to physical health and fire risk, but also one of psycho-emotional health and wellbeing.

### 4.3. Issues for municipal engineering staff

At issue was not merely whether and how to get sufficient and suitable water to the residents of Senanus Drive, but also whether any changes would incur further development of the area. The senior engineering technologist for Central Saanich was asked to prepare a report to council to summarise the results of all other reports and to propose a series of policies and options. A large part of the report focused on the Official Community Plan and land use bylaws. (The report had been reviewed and endorsed by the director of financial services and the director of planning and building services. Furthermore, a municipal engineer and clerk administrator had signed to concur with the recommendations.) In particular, the report detailed that existing documents did not allow the subdivision of existing rural and agricultural properties for the development of new housing units.

Previous municipal engineering recommendations had advised against a connection from the Brentwood Bay area northward, which would have potential problems with the First Nations community that the pipe would have to cross and which would be about 30% more expensive than the actually proposed extension. A potentially viable solution, a community cistern at a cost about equal to the watermain extension, was rejected by the municipal engineer in a memo (17 October 1997) to the municipal council: 'In view of the conflict with provincial policy, probable non support of the residents, costs, and requirements for significant further engineering studies, this alternative is not recommended'.

The diameter and location of every water service connection being at the sole discretion of the municipal engineer (bylaw no. 1410), engineering staff had to make a decision concerning the size of the supply line. The existing watermain at the east end of Mount Newton Cross Road (Fig. 2) is an old 10 in (300 mm) diameter steel. Computer simulations indicate that an 8 in (200 mm) pipe extending to West Saanich Road and a 6 in (150 mm) pipe to the westernmost point would be sufficient. Because of elevation changes along Mount Newton Cross Road, pressures would average about 50 psi (3·35 bar) in the summer, with lower values during peak hours and 130 psi (8·96 bar) high values in the Senanus Drive area, raising the possibility of the requirement for a pressure-reducing valve chamber. The report prepared by the municipal engineers (including all technical reports) was made available at an open-house event, which was followed by a public meeting where the pertinent issues were to be presented and discussed.

### 4.4. All's well that ends well(s)?

On 7 December 2000, the Saanich Peninsula Water Commission carried a motion according to which it declined taking a position on the matter of a watermain to Senanus Drive and Mount Newton Cross Road because it was considered a municipal rather than a regional issue. The municipal council defeated a motion that requested the support and authorisation of 'a waterline extension to be fully funded by the Senanus residents'. In subsequent years, however, the issue concerning health and safety became increasingly salient, in part perhaps because of the increasing number of national reports about contaminated municipal water supplies, including one in Waterton, Ontario, where seven individuals died after consuming *E. coli* contaminated water from the municipal watermain. On 23 May 2001, the CRD board charged the regional medical health officer 'to review all reports on the Senanus water quality issue and to provide a report to the Board as to the extent of the health hazard'. During the debate, water quality, water quantity, development versus non-development, local government autonomy and infrastructure issues were discussed as well as the legal implications for not responding to the matter. On 12 September 2005, the water and waste management committee moved and carried a recommendation for its support 'of Staff providing a positive recommendation on watermain extension applications, subject to the requests being technically, environmentally, and financially feasible from an infrastructure, environmental, and cost recovery perspective'. By 2006, the municipal council had recognised the water safety issue as a pressing public health and environmental issue and one of fire hazard to agricultural properties. On 11 December 2006, a consultant from Bullock Baur advised the municipal council of four options

(*a*) domestic water supply only
(*b*) domestic and agricultural water supply and fire flow
(*c*) domestic water supply and fire flow of 80 l/s
(*d*) domestic water supply and agricultural water of 280 l/s.

On 29 January 2007 a motion was proposed and carried (three for, two against) to support the municipal rural infrastructure fund programme application as a priority number one project.

After years of further wrangling, letter writing, discussions, etc., the municipality, through its engineering staff, finally submitted a grant application that was funded in August 2007 at a level of about $1 600 000—nearly three times the initial cost estimate. The costs were shared in equal parts by the federal, provincial and municipal governments. Among the reasons that brought about this change in public policy and decision-making were an increasing sensibility and concern for public health, safety (fire hazard) and environmental concerns. The federal government news release on the occasion clearly indicates safety as the main issue ('Safe water for central Saanich residents').[8] The release stated that the joint investment would help 'build health, clean and prosperous communities' by providing a 'source of safe and reliable drinking water'.

## 5. CONFLICTING INTERESTS, POLITICS

A special occasion allowed all major stakeholders and players to come together and discuss the pertinent dimensions of the issue. On 22 September 1999, municipal engineering staff organised a 1·5 h open-house event where copies of all reports were made available. This event was followed by a public meeting in which technical and advisory bodies made presentations (45 min), the public could ask questions directed towards the technical presentations (15 min) and members of the public could comment. Because the municipal engineering department organised the event, it found itself charged with bias and explicitly and implicitly supporting an outcome desired by the anti-watermain side.[9]

### 5.1. Is the science good?

Municipal engineering staff were asked to evaluate evidence of very different kinds (scientific analyses, testimonials) and of contradictory nature in the scientific findings. On the one hand, there were the findings of Lowen Hydrogeology, which, having undertaken sampling in the month of April, found that besides some aesthetic problems (certain contaminants were above the thresholds recommended by Canadian guidelines), there were no problems with the water, especially no biological problems. On the other hand, tests conducted by Giles Environmental Engineering and the CHR, including multiple testing during the year, did show problems with chemical and biological contaminants. The facts themselves appeared to be contaminated and it was difficult to distinguish hard fact from soft. Those against a watermain extension argued that the tests done by CHR and others were essentially flawed and that the Lowen study was the only scientifically reliable analysis. Those in favour of an extension grounded their argument in the CHR study, previous scientific analyses and the anecdotal evidence available.

One of the publicly discussed issues concerning the quality of the science behind the reports related to the date and frequency of sampling. On the one hand, Lowen tested only once, at a point in time when groundwater levels were slightly higher than average; it was claimed that this represented average concentration. Is this a hard fact? On the other hand, CHR tested repeatedly at different times of the year and found variations in the parameters. Should we take this as hard fact? The available testimonial evidence pointed to a decreasing quantity of water over the previous four decades and significant problems affecting quality of life, equipment, installations and the environment. How should municipal engineers evaluate this evidence? Soft facts? Hard facts? It appears evident that for extended periods of time, the water was low and the contaminant concentrations concomitantly high. Continuous water supply was not possible, especially during drought periods, limiting the already limited fire-fighting capabilities even further. A well-known ocean scientist who resides in the area suggested during the public meeting that sampling methods based on one sample alone are insufficient on scientific grounds. The problems for evaluating the factual issues were exacerbated because the same individuals contradicted themselves. For example, one participant claimed in one and the same breadth that 'all the fresh water that got in the aquifer came from rainwater' on the one hand and 'I know that it was a record period per rainfall but it's not reflected in water levels' on the other.

An environmental policy analyst present during the public meeting suggested that science had been 'misused by both sides [of the issue], as it is being used as an authoritative voice which is supposed to decide the conflict'. He emphasised a lack of analysis of biofilms and bacterial contamination of water pipes, and that water hardness could exacerbate the problems. He also critiqued the sampling method, pointing out by referring to a hydrogeology graph that the Lowen study had sampled at a point in time when the water was above median level.

Where the water was sampled also came under scrutiny. Lowen claimed that CHR had tested the water inside houses, a claim that a CHR officer refuted. In fact, its report explicitly excluded one well measurement because it appeared to have sampled previously mitigated water rather than water from the well. The Lowen testing too came under scrutiny, as the claim to have sampled 'as close to the well as possible' and before the water made it through water mitigation devices did not hold up during the meeting where residents showed that unmitigated water *could not have been measured.*

### 5.2. Stopping development

In the face of concerns on the part of some residents of the Mount Newton Cross Road area and of some council members with respect to land development, the municipal engineering department was also asked to evaluate the potential for land development; this potential was to be weighed against the issues of safety related to fire, health and environment even though the two domains may be considered incommensurable. One of the declared fears on the part of residents in the Mount Newton Cross Road area related to a potential change in zoning regulation and land development. The mayor had repeatedly articulated in public meetings and in the media that his council voted against the watermain extension in order to stop development: 'it's a long-time municipal policy to keep potable water away from people living on Senanus Drive. That way the municipality discourages future development'.[10]

However, there was precedent in the community that the construction of a watermain would not change the essentially rural character of an area in the municipality. Engineering staff pointed out that there were two other areas (Oldfield Road and the eastern part of Mount Newton Valley) where the introduction of a watermain had not been followed by development and had, in fact, allowed the expansion of agricultural businesses (e.g. wineries) that now had access to sufficient water. Those advocating the construction—a minority of the WATF—suggested that failure to construct a watermain had the potential to diminish the possibility to generate income from farming, entailing abandonment of farming and subsequent redevelopment.

### 5.3. Who bears the costs?

In 1995, a municipal engineer estimated the cost for laying of an 8 in pipe to be about $800 000; one year later, a local contractor submitted a proposal estimating the cost at $610,00. If the 64 properties were to have carried the costs on their own, this would have amounted to between $10 000 and 12 500. An alternative route from the south and through the First Nations reserve would exceed $1 000 000. Alternative costing based on assessment values varied from $1500 to $65 000.

The cost factors involved are very different in nature and also include environmental dimensions. Problems with diminishing and unreliable water supply are due to the heavy use of groundwater for irrigation purposes on which the farms along Mount Newton Cross Road rely. The costs of this environmental problem are incurred by some (farmers, generally against a watermain extension, who deplete the aquifers) but are borne by others downstream (overwhelmingly in favour of an extension). Furthermore, previous technological solutions frequently did not help. For example, one resident installed a water softening system that later had to be disconnected because the already high sodium concentration of their water increased even further. Information provided to the attendees of the open-house meeting suggested that chromium treatment was not possible. Furthermore, individual solutions were costed at $50 000 and above, whereas a watermain would be less costly to the individuals collectively.

### 5.4. Municipal politics

Various interests mediated the responses of those who would be connected to the watermain and who might have to bear the financial costs. Those living on the western end of the area involved (Senanus Drive and western parts of Mount Newton Cross Road), with poor water quality and quantity, overwhelmingly favoured the watermain extension. Those who had an ample supply of groundwater in the more eastern parts were predominantly against the extension, as were some residents who had moved to the area because of its rural nature and some council members who wanted to make sure that the area would not be developed. In the proceedings of the UNESCO-sponsored conference *Frontiers in Urban Water Management*, the chair of the WATF wrote that he had moved to the area to escape urban sprawl and that the watermain extension would encourage further development. He and others used various means to discredit the position of the other side. Strategies, including 'working on those who do not need the watermain', would be easier to impede with the 50% of the properties representing two-thirds of the land value requirement (under the petition method) for adopting a resident-funded watermain. Leaflets were distributed highlighting the financial costs to be borne and the self-serving nature of the already rich pro advocates. The WATF chair, the leading opponent to the watermain extension, repeatedly labelled the CHR report as flawed and attempted to prevent others to speak out because their contributions were non-technical. Other issues were at stake as well, which became apparent because, as was made public during the meeting, the WATF chair had stocks in a company that provided alternative water treatments in the area.

## 6. MUNICIPAL ENGINEERS BETWEEN A ROCK AND A HARD PLACE

Municipal engineering staff frequently found themselves exposed to opposing parties, as they were tasked with liaising between council and the WATF, and writing memorandums presented to council or the Water and Waste Management Committee. In the course of the conflict, different municipal engineers and engineering staff acted differently with respect to commitments to solutions. Some simply stated options without weighing costs, whereas others explicitly recommended against certain solutions.

In the public, there frequently was a perception—both during meetings and in interviews conducted subsequently—that the municipal engineering staff were biased and taking sides.[9] A senior engineering technologist distinguished between technical information on the one hand and 'opinion', 'mud slinging', 'bashing', 'public comment', 'bias', 'concern', etc. on the other. The technical information was associated with people whose engineering degrees were read out; anecdotal and other forms of information with residents who spoke out. The author of the WATF majority report reiterated the same sentiment, attempting to drive a wedge between his favoured information associated with the adjective 'technical' and other information labelled as 'hearsay'.

## 7. CONCLUSIONS AND RECOMMENDATIONS

With a limited budget for public works, trade-offs exist between the benefits of conventional solutions (often high up-front costs) and alternative approaches that address a broader set of priorities. Thus, generic municipal engineering standards have been developed to ensure the construction of waterworks from centralised sources that supply large numbers of homes. However, alternative solutions may be able to meet more diverse, individual and local needs. Cost comparisons therefore cannot be made on mere technical grounds but require making explicit choices among policy objectives. Municipal engineers, responsible for the improvement, operation, design, construction, review, inspection and maintenance of the watermain found themselves at the intersection of varied forms of knowledge, interests and needs. More than any technical issue, the human and social issues became stressors for the municipal engineering staff, whose mandate also was to respond to public inquiries, to mediate situations where opponents confronted each other and to respond to repeated requests for documentation by the media and then public.

This case study shows how municipal engineers, tasked by the municipal council with providing a recommendation on the issue, were confronted with very different kinds of knowledge and with facts of different 'hardness'. Even some of the facts provided by scientists and engineers turned out not to be so hard and repeatedly were in conflict with each other. Some of the evidence came from 'soft facts' that showed the 'hard facts' where not as hard as these were thought and held to be. The question that poses itself to the municipal engineer therefore is of both epistemic (i.e. which knowledge and facts to include in the decision-making process) and ethical (i.e. making recommendations that are also defensible on the grounds of distributive social justice). There is evidence that at least some of the municipal engineers involved in the issue over the years were sensitive to the complexity of the issues that went beyond simple technical questions and legal obligations with respect to the provision of water to the area. At the time of writing, upon the recommendations of municipal engineers, the council decided not to support the construction of a watermain extension along Mount Newton Road to Senanus Drive.

In an increasingly sensitive climate (politically, ethically, environmentally), municipal engineers have to draw on tools and techniques that will allow them to deal with diverse forms of knowledge and with facts whose status cannot be taken as absolutely hard and irrefutable even when provided by experienced engineers and scientists. How can municipal engineers think about such integration? Two ways of approaching such a task are now suggested.

The method of Bayesian inference is good example of how prior knowledge and beliefs can be integrated in the construction, testing and updating of scientific hypotheses. The method allows integrating subjective possibilities concerning the hypotheses they make about the outcome of an experiment. In fact, a most recent formulation of Bayesian decision theory allows the integration of factual and conditional possibilities and different degrees of rational beliefs and desires.[11] Such decision-making support therefore would be important in the face of the different interests and intentions at play in the Senanus Drive water issue. Bayesian networks constitute decision support systems that allow large amounts of uncertain reports from different sources, including other decision-makers' reasoning about the decision-maker's reasoning, to be integrated to provide comprehensible information.[12] Bayesian networks are graphical representations of qualitative uncertain knowledge concerning the relations (conditional dependence, independence) among propositions.

There are other formal methods available for the integration of scientific and testimonial information, as shown by the 'back-to-the-future' approach to modelling and evaluating present and past ecosystems.[13] These methods draw on traditional and local ecological knowledge (e.g. relative consumption of different marine species by different tribes in the area), historical documentation (archival documents) and archaeology (including ancient DNA and molecular archaeology) to validate ecological modelling of species using ecological modelling software techniques. Thus, Ecopath is a mathematical model that includes time-dynamic (Ecosim) and spatial simulation (Ecospace) methods that can be used to study fisheries resources in an ecosystem context for overall analysis and for exploring management policy options. Rather than overpowering traditional and local ecological knowledge, the back-to-the-future approach actually strengthens it and gives it a voice in the shaping of future policies. Such an approach would be relevant in the present situation where there is historical and local testimony that was not sufficiently appreciated at least initially. How such an approach would work in the context of municipal engineering is beyond the scope of this paper, but the following brief description should suffice for articulating how the approach works conceptually.

The ecology of water in a watershed can be conceptualised in terms of a flow model (Fig. 7). The model is quantitative and for many quantities there are already continuous records, e.g. those concerning water levels in a creek, at various points in the ground and in a number of wells. Quantitative records of daily rainfall are also available for several decades as well as the various scientific measurement episodes of water quality at

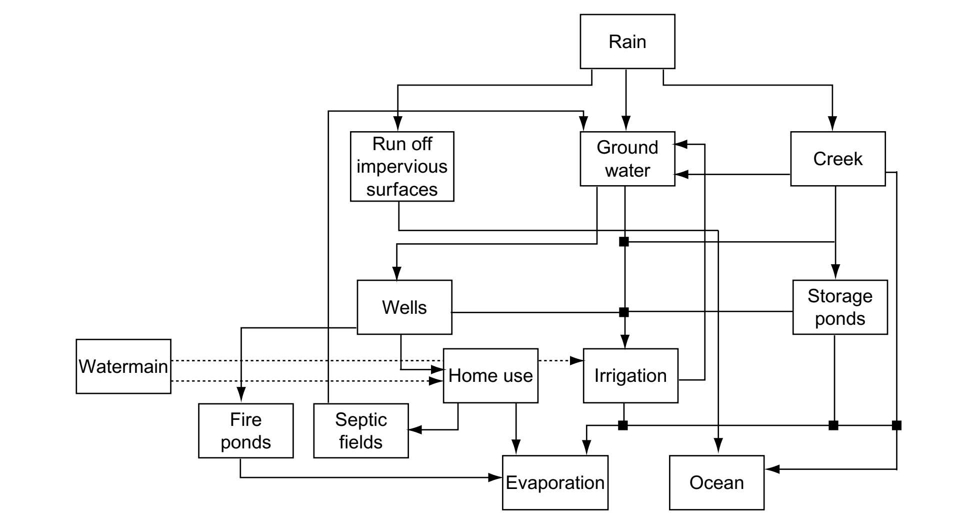


Fig. 7. Model for water ecology without and with additional supply by means of a watermain

different times of the year and for different years. If all information were available, the model would be no more complex than those used by some educators with middle-school students using software that visually models ecosystems.[14] The advantage of the Ecopath approach is that it allows estimation of uncertain parameters that derive from anecdotal evidence, e.g. in the form of anecdotal reports on the availability of water over past decades, contaminant levels, or weather patterns and their relation to water quantity. The model provides estimates for the parameters used in quantitative evaluations based on anecdotal evidence, which is used as antecedent information that modifies actual inputs from acceptable inputs. Ecopath also provides fuzzy logic for model balancing, incorporation of seasonal and time series data, and tracking of pollutants. As Fig. 7 shows, municipal engineers could model the impact a new watermain would have for different scenarios, including increasing housing density or changes in irrigation. As explained by fisheries scientists, Ecopath offers a way of linking scientific data and modelling with various forms of local knowledge taken into consideration by First Nations people and fishermen (e.g. target species, prey, weather, currents, tides, Moon phases).

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