Report prepared for the Ministry of Health

The 2012 waterborne disease outbreak in a small town in New Zealand: an estimate of costs

David Moore, Eva Hendriks and Craig Wright

20 December 2013

sapere®
research group

About Sapere Research Group Limited

Sapere Research Group is one of the largest expert consulting firms in Australasia and a leader in provision of independent economic, forensic accounting and public policy services. Sapere provides independent expert testimony, strategic advisory services, data analytics and other advice to Australasia's private sector corporate clients, major law firms, government agencies, and regulatory bodies.

Wellington Level 9, 1 Willeston St PO Box 587 Wellington 6140 Ph: +64 4 915 7590 Fax: +64 4 915 7596	**Auckland** Level 17, 3-5 Albert St PO Box 2475 Auckland 1140 Ph: +64 9 913 6240 Fax: +64 9 913 6241	
Sydney Level 14, 68 Pitt St GPO Box 220 NSW 2001 Ph: + 61 2 9234 0200 Fax: + 61 2 9234 0201	**Canberra** Unit 3, 97 Northbourne Ave Turner ACT 2612 GPO Box 252 Canberra City, ACT 2601 Ph: +61 2 6267 2700 Fax: +61 2 6267 2710	**Melbourne** Level 2, 65 Southbank Boulevard GPO Box 3179 Melbourne, VIC 3001 Ph: + 61 3 9626 4333 Fax: + 61 3 9626 4231

For information on this report please contact:

Name:	David Moore
Telephone:	+64 4 915 7590
Mobile:	+64 21 518 002
Email:	dmoore@srgexpert.com

Contents

Executive summary .... **vii**

1. Introduction **1**

1.1 Purpose of this report 1
1.2 The setting: a small rural township 1
1.3 The event: a series of water quality system failures 1
1.4 Structure of this report 2

2. Understanding the disease **3**

2.1 A common bacterial infection 3
2.2 Most sufferers recover quickly at home... 3
2.3 ...but serious complications sometimes occur 4
2.4 How we defined a 'case' 4
2.5 Estimating the total number of cases 5
2.5.1 People told to not visit their GP 5
2.5.2 The general practice told to stop testing samples 5
2.5.3 Over-the-counter sales also biased 5
2.5.4 So we took a median value 6

3. Approach to costing **7**

3.1 Broad approach of 'cost of illness' assessment 7
3.2 Identifying the cost categories 7
3.3 A note on treatment of data 8
3.4 Estimating and valuing the costs 9
3.4.1 Direct health costs 9
3.4.2 Lost productivity of patients 11
3.4.3 Lost productivity of carers 12
3.4.4 Missed days of school 12
3.4.5 Transport costs 13
3.4.6 Health outcomes 13
3.4.7 Costs to authorities in dealing with the outbreak 14
3.4.8 Costs of the aftermath of the outbreak 14
3.4.9 Costs of managing water quality during the outbreak 15
3.4.10 Loss of faith in water quality 15
3.5 Summary of our method 18
3.6 Choosing the time period for analysis 18
3.7 Defining the population and area 19

4. Analysis and results **21**

4.1 Central estimates 21
4.1.1 Direct health costs ($191,162) 21
4.1.2 Lost productivity of patients ($126,474) 25
4.1.3 Lost productivity of carers ($30,183) 25
4.1.4 Missed days of school (871 days) 26
4.1.5 Transport costs ($1,690) 29

4.1.6 Health outcomes (1.087 loss in DALYs) 29
4.1.7 Costs to authorities in dealing with the outbreak ($45,000) 30
4.1.8 Costs of the aftermath of the outbreak ($1,115) 30
4.1.9 Costs of managing water quality during the outbreak ($9,743) 30
4.1.10 Loss of faith in water quality ($694) 31
4.2 Total costs 31
4.3 Caveats and limitations 32
4.4 Sensitivity analysis 33

Appendices

Appendix 1 References 35

Appendix 2 Data sources 41

Appendix 3 Analysing sequelae: Guillain-Barré syndrome 42

Tables

Table 1 Estimate of total number of cases 6

Table 2 Costs included in our assessment 8

Table 3 Costing units 17

Table 4 Case and control area units and populations 2012 20

Table 5 Estimated Disability Adjusted Life Years 30

Table 6 Sensitivity analysis of costs estimates, with varying number of cases 34

Table 7 Sensitivity analysis of costs estimates, with and without a GBS case 34

Table 8 Data sources 41

Table 9 Sizes of campylobacter and non-campylobacter population in the Town's area 43

Table 10 Probability of GBS case conditional on campylobacter infections 45

Figures

Figure 1 Sequence of events 2

Figure 2 Summary of our method 18

Figure 3 Period for analysis 19

Figure 4 GP Consults for PHU case group 21

Figure 5 The Town's Pharmacy Over-the-Counter sales of anti-diarrhoeal drugs 22

Figure 6 Pharmaceutical dispensing co-payments for PHU case group 22

Figure 7 Pharmaceutical drug price for PHU case group 23

Figure 8 Total laboratory test price for PHU case group 25

Figure 9 The Town's pre-school absences due to sickness 27

Figure 10 Neighbouring primary school absences due to sickness 28
Figure 11 The Town's high school absences due to sickness 28
Figure 12 Total estimated costs of the outbreak 32
Figure 13 Break-down of costs per cost bearer 32

Executive summary

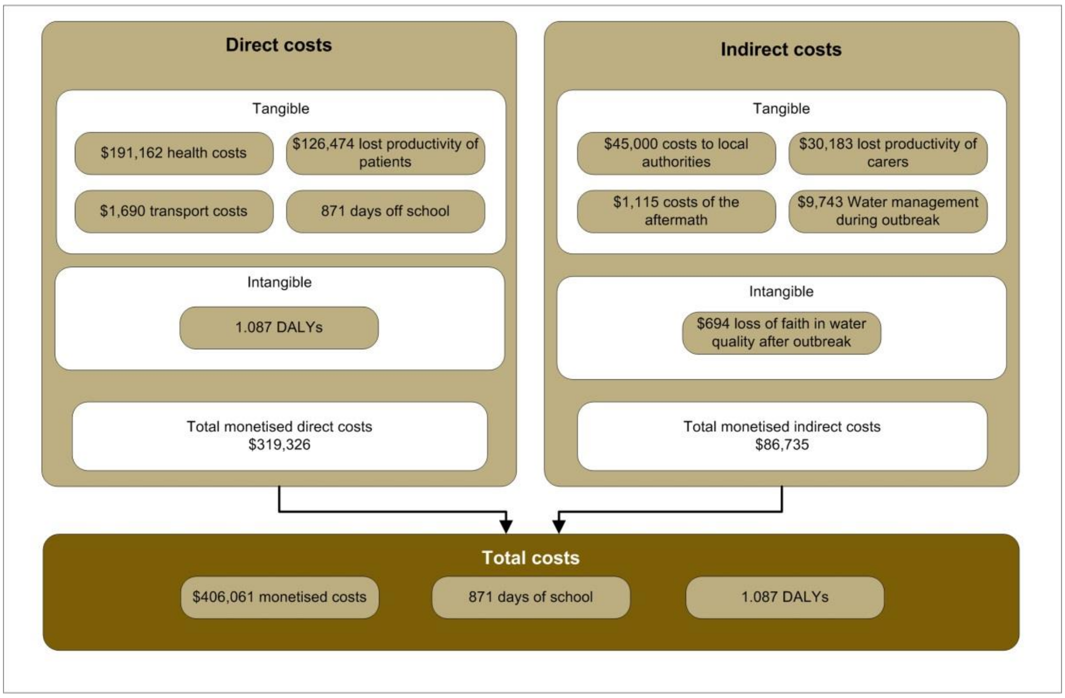
We were commissioned by the Ministry of Health to provide an estimate of the costs of the 2012 outbreak of campylobacter, a gastrointestinal disease, in a South Island township.

We estimated that there were a total of 413 cases of campylobacter during this outbreak. We took a 'cost of illness' approach to quantifying and monetising the cost of these cases, based on relevant literature from New Zealand and overseas. We drew heavily on the approach to valuation of costs taken by LECG in their 2010 cost benefit analysis of raising the quality of New Zealand's networked drinking water, seeking to recalibrate and implement the estimates used in the LECG study to the extent possible with the available data.

We assessed the costs on the public health system, to the individual patients themselves, and to those caring for the patients at home and in rest homes. We also estimated the additional costs to local authorities of responding to and managing the outbreak (over and above what they would normally incur as part of their roles).

We estimated that the total costs able to be monetised amounted to $406,061. In addition, we calculated that school children missed 871 days of school due to this illness, and that the community suffered a loss of 1.087 disability-adjusted life years.

A sensitivity analysis based on the lowest and highest plausible estimates of campylobacteriosis cases (Table 1) identified ranges of total monetised costs of $308,592-$536,401, 871 days off school and 0.93-1.31 DALYs.



1. Introduction

1.1 Purpose of this report

We were commissioned by the Ministry of Health to provide an estimate of the costs of the 2012 outbreak of campylobacter, a gastrointestinal disease, in a South Island township.

This report has been peer reviewed by Dr. Ian Sheering BSocSci, MA (Hons), DHSM, PhD, JP Health Economist & Senior Lecturer, Public Health at Otago University. We are grateful for his comments and recommendations.

1.2 The setting: a small rural township

The outbreak happened in a township on the South Island of New Zealand, located 35 kilometres from a medium to large city. For privacy reasons in this report, we will refer to this township as "the Town", and to the nearby city as "the City". It has a population of between 1000 and 2000, many of whom commute to work in the City. Some of the Town's children attend school out of town, while other children from neighbouring surrounds attend school in the Town. In addition, many households in the Town do their grocery shopping in larger neighbouring towns or in the City itself; factors which, as we discuss later, all affected our costing methodology.

1.3 The event: a series of water quality system failures

The Town's main water supply has two sources:

1. **Old source** – comprising infiltration galleries from a nearby River. This water is chlorinated for consumption.
2. **New source** – a deep bore that has been in use for approximately 12 months, and was expected to provide more security of supply in terms of water levels.

Due to a pump failure at the new source, the water supply reverted to the old source on t-32. A combination of process factors then contributed to a subsequent contamination of the old source:

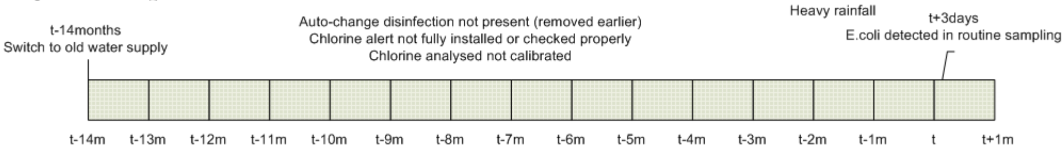
- The auto-change for disinfection of the old source had been removed following the switch to the new source;
- The system that provides a warning when the chlorine runs out was not fully installed at the old sources, nor was this properly checked for; and
- The chlorine analyser at the old source was not calibrated.

There was also a period of heavy rainfall in the catchment area. For anonymity reasons we will suppress the exact dates of the events. We will refer to the timing of events relative to the start of this heavy rainfall period.

The heavy rainfall occurred on t and t+1, which resulted in higher levels of surface water run-off into the old source between t and t+6, and may have exacerbated the problem.

On t+3, routine weekly water sampling detected high levels of Escherichia coli bacteria (E. coli) in the town water supply. The Town's Medical Centre notified the local Public Health Unit (PHU) on t+9 of 13 cases of gastroenteritis, at which time the PHU started an outbreak investigation, which lead to confirmation of the causes of the outbreak. On t+4 a boil water notice was issued by letter to residents. On t+8 the boil water notice was rescinded and the following day the new water source was brought back on line.

Figure 1 Sequence of events



During the outbreak, there were 54 presentations to GPs and 29 laboratory-confirmed cases of campylobacter. However, this is expected to be an under-estimate of the actual number of cases for a number of reasons, including:

- Laboratory tests were ceased after an official outbreak was confirmed;
- As we explain later in our report, most people suffering from campylobacter do not visit their GP, and therefore are not represented in lab results; and
- Once the outbreak was confirmed, residents were instructed by the general practice to not present to their GP, a factor which further reduced the accuracy of the official number of cases.

1.4 Structure of this report

In section 2, we explain our methods for adjusting for the factors listed above, in order to arrive at an estimate of the actual number of campylobacter cases. We then describe the various categories of costs that we included and how these were modelled in section 3 and results are presented in section 4.

2. Understanding the disease

2.1 A common bacterial infection

Campylobacteriosis is a common infectious disease caused by bacteria of the genus campylobacter. It can be contracted by both waterborne and food-borne pathogens; with common transmission mechanisms being consumption of contaminated drinking water, poor hand-washing practices, and ingestion of unpasteurised milk or raw chicken.

Campylobacteriosis continues to be the most commonly notified disease[1] in New Zealand. In 2012, there were 7,031 notified cases – a rate of 158.6 per 100,000 population, and comprising 34.7% of all notifications in that year. The campylobacteriosis rate varied throughout the country, with higher notification rates in the South Island of New Zealand.

Hospitalisation status was recorded for 4370 (62.2%) cases of which 459 (10.5%) were hospitalised at a rate of 10.4 per 100,000 population.

About one quarter of people with a notification of campylobacteriosis in 2012 and who reported exposure to campylobacteriosis risk factors consumed untreated water.[2]

The number of notified cases is understood to be far lower than the actual number of cases, for reasons we explain below. The total number of 2012 campylobacter infections in the community is conservatively estimated at 53,400 per annum (based on a widely used multiplier of 7.6 times the number of notified cases) or a rate of 1,200 per 100 000 population.[3]

2.2 Most sufferers recover quickly at home...

Most people who become ill with campylobacteriosis get diarrhoea, cramping, abdominal pain, and fever within two to five days after exposure to the organism. The diarrhoea may be bloody and can be accompanied by nausea and vomiting. Recovery usually takes between two and five days, though sometimes up to 10 days.

Most people who contract the disease recover at home and do not visit a GP. Around 5% of these cases will treat themselves with over-the-counter anti-diarrhoeal and/or oral rehydration medication.[4]

1 Notifications to the medical officer of health of specified diseases under the Health Act 1956.

2 The Institute of Environmental Science and Research Ltd (2012) *Notifiable and other diseases in New Zealand: Annual report 2012* (Institute of Environmental Science and Research Ltd: Porirua, New Zealand).

3 J. G. Wheeler et al. (1999) 'Study of infectious intestinal disease in England: rates in the community, presenting to general practice, and reported to national surveillance,' *BMJ* 1999 (318): 1046-50.

4 D. Moore et al. (2010*) Cost benefit analysis of raising the quality of New Zealand networked drinking water* (LECG: Wellington, New Zealand).

According to the New Zealand literature, up to a third of people who contract campylobacteriosis will visit a GP.[5] Approximately 31% of these patients may be asked to provide a faecal sample for laboratory testing, with around a 90% compliance rate. Of the tests conducted, around 20% of these will test positive for a pathogen (Lake et al., 2009).

2.3 …but serious complications sometimes occur

Campylobacteriosis can lead to more serious outcomes. Recent New Zealand research estimates that 0.77% of cases lead to hospitalisation. There is also a small chance (0.001%) of fatality.[6]

Campylobacter infection can also result in long-term consequences (sequelae). Some people (2.4-2.6% of cases) develop reactive arthritis. Others may develop a rare disease called Guillain-Barré syndrome (GBS) that affects the nerves of the body beginning several weeks after the diarrheal illness. This occurs when a person's immune system is triggered to attack the body's own nerves resulting in paralysis that lasts several weeks and usually requires intensive care. It is estimated that approximately one in every 1,000 reported campylobacter illnesses leads to GBS (Cressey and Lake, 2007 and 2008).

Campylobacter, along with all other forms of acute gastrointestinal illness (AGI), is also understood to contribute to irritable bowel syndrome (IBS) (around 0.04% of cases) (Cressey and Lake, 2007 and 2008). In people with compromised immune systems, campylobacter occasionally spreads to the bloodstream and causes a serious life-threatening infection.[7]

2.4 How we defined a 'case'

The local Public Health Unit (PHU) provided us with a case definition that they developed specifically for this analysis. A case was defined as:

> *a person who had been in [the Town] between [t-30] and [t+17], who was not overseas during the 10 days before the onset of symptoms and for whom there was no medical or other likely explanation for their symptoms and who had either:*
>
> – *diarrhoea and/or abdominal pain with fever - for at least one day (probable case of campylobacteriosis), or*
>
> – *a laboratory confirmed notifiable enteric disease (confirmed case), or*

---

5 D. R. Lake (2009) *Acute gastrointestinal illness (AGI) study: final study report* (ESR: Wellington, New Zealand); S. Perera and B. Adlam (2007) *Acute gastrointestinal study: general practice study* (ESR: Wellington, New Zealand); N. King et al. (2007) *Acute gastrointestinal illness study: laboratory survey* (ESR: Wellington, New Zealand); B. Adlam et al. (2009) *Acute gastrointestinal illness (AGI) study: community survey* (ESR: Wellington, New Zealand).

6 P. Cressey and R. Lake (2007) Risk ranking: estimates of the burden of food-borne disease for New Zealand (Institute of Environmental Science and Research Ltd: Wellington, New Zealand); P. Cressey and R. Lake (2008) Risk ranking: estimates of the cost of food-borne disease for New Zealand (Institute of Environmental Science and Research Ltd: Wellington, New Zealand).

7 Centres for Disease Control and Prevention.

– *diarrhoea (> 3 episodes of liquid/loose stool in 24 hours if frequency known) and/or vomiting (> 3 episodes in 24 hours if frequency known) and/or any two of abdominal pain, nausea, fever - for at least one day (probable case of gastroenteritis).*

2.5 Estimating the total number of cases

The PHU identified 166 possible cases and excluded 28 on the basis of the case definition. Of the remaining 138 cases fitting the definition, 29 were confirmed through laboratory testing as campylobacter. Given that most people who contract campylobacter do not visit a GP (and are therefore not represented in official statistics), we then needed to estimate the total actual number of cases.

Although there are various ratios in the literature that can help us with this estimation (which are summarised above), there are a number of biases in the data for this particular outbreak.

2.5.1 People told to not visit their GP

A few days after the start of the outbreak, it was clear to the GPs and nurses at the Town's single general practice that there was a campylobacter outbreak. They began advising patients who contacted the practice regarding gastrointestinal problems to not come in, as a GP or nurse consultation was not expected to assist with their recovery. Advice was instead provided over the phone. This means that estimates based on GP visits using ratios from unbiased numbers would result in an underestimate of the actual number of cases.

2.5.2 The general practice told to stop testing samples

At the beginning of the outbreak, GPs decided to ask for faecal samples for testing from every patient that came in with gastroenteritis. After a few days, the Ministry of Health requested that the practice stop requesting laboratory tests, as the cause and treatment was known and further testing would just result in unnecessary costs. However, an information phone line was provided, and people phoning this number who had symptoms were advised to bring in a sample to the general practice. We are unclear what happened to these samples (i.e. whether they were sent for testing or discarded). Either way, the combination of these factors means that estimates based on a ratio of the number of positive faecal tests would be strongly biased. To illustrate this, when we applied the ratio from Lake et al. (2009) of 31% we came up with an estimate of 2,416 cases, which is greater than the total population of the Town. We therefore discarded this estimate.

2.5.3 Over-the-counter sales also biased

Another way of deriving an estimate of total cases is to use the amount of anti-diarrhoeal and oral rehydration medication sold over-the-counter (OTC) in community pharmacies. Consistent with the method applied by LECG in 2010, we obtained sales data from the single pharmacy in the Town. But, as shown in the following table, when we applied the ratios in the literature, a wide disparity of figures was produced. One explanation for this is that some of the anti-diarrhoeal medication was sold in larger family packs of 20 caplets, which could be serving more than one case in the same household.

In addition to these sources of bias, we also know that many the Town's residents routinely do their shopping outside the area, which is likely to introduce another source of bias.

2.5.4 So we took a median value

In light of these biases, we opted to use a modest estimate by taking the median of four estimates produced – those based on GP visits, OTC sales of two products, and an estimate produced by the general practice manager. (As mentioned above, we excluded the estimate based on positive faecal tests.) The practice manager's estimate turned out to be right in between the two estimates based on OTC sales.

Table 1 Estimate of total number of cases

Based on	Measure	Ratio	Value	Estimated # of cases not visiting GP	Estimated total # of cases
Lake et al. 2009, Adlam et al. 2009, Lake et al. 2009, Cressey and Lake 2007 and 2008, Kemmeren et al. 2006[8]	# of visiting a GP	19.7% - 34.1% of total # cases	54 GP visits		158-274
Lake et al. 2009	# positive faecal test results	1.2 % of total number of cases	29 positive results		2,416
LECG 2010	# over the counter oral hydration drugs sold	5% of all cases that do not see a GP	35[9]	700	754
LECG 2010	# over the counter anti-diarrhoeal drugs sold	5.2% of all cases that do not see a GP	12[10]	231	285
Estimate by the Town's General Practice manager	# GP visits	10%	54 GP visits		540
Estimate selected					**413**

8 J. M. Kemmerman et al. (2006) *Priority setting of food-borne pathogens. Disease burden and costs of selected enteric pathogens* (The Netherlands).

9 Over the period t-1 to t+18, 35 packages of 10 sachets of Enerlyte Rapid restore and Enerlyte Rehydration salts were sold at the single pharmacy in the Town.

10 4 packages of 8 Imodium caplets, 2 packages of 6 Imodium Zapids and 6 packages of 20 Imodium caplets were sold over the period t-1 to t+18, sold at the single pharmacy in the Town.

3. Approach to costing

3.1 Broad approach of 'cost of illness' assessment

This report consists of a cost of illness assessment (COI). This method seeks to estimate the burden of illness to individuals and society in terms of the expenditure or resource loss resulting from the illness. We do not provide an economic analysis of possible policy decisions affecting such costs, as would be the case with a Cost benefit analysis, a cost effectiveness analysis or a cost utility analysis.

For our assignment, we were asked to solely consider costs, and only those costs arising from this specific outbreak. We were not asked to estimate to total burden of campylobacter on the population, or to value the benefits of potential improvements to drinking water supply. The most appropriate analytical method is therefore COI. However, we did refer to other types of studies for determining how to value particular costs. In particular, we sought to implement the costing approach taken by LECG in their 2010 CBA as far as possible.

We found two (co-published) studies that estimated the incidence and cost of food-borne AGI in New Zealand, as well as a variety of international studies, and drew on these to establish our cost categories and assumptions.[11]

3.2 Identifying the cost categories

We sought to take a broad approach to identifying types of costs, in order to form as comprehensive an assessment as possible. Based on the literature, we classified costs into the following four categories:

1. **Direct costs**: those directly attributable to a specific case/patient (although potentially the cost is paid by someone else, e.g. the DHB);
2. **Indirect costs**: costs that are not directly attributable to a specific case (instead these are costs of the fact that there is an outbreak);
3. **Tangible costs**: those costs that are measurable or otherwise quantifiable (though not necessarily in dollar values); and
4. **Intangible costs**: costs that are not straightforward to measure/quantify.

The following table sets out the types of costs we included in each category.

---

11 Including G. W. Scott et al. (2000) 'Economic cost to New Zealand of food-borne infectious disease', *NZMJ*, 14 July 2000; and Cressey and Lake (2008).

Table 2 Costs included in our assessment

Cost category	Cost type
Direct tangible	• Health costs – OTC sales of anti-diarrhoeal drugs and oral rehydration products – Community pharmaceutical dispensing (prescriptions) – Public hospital admissions – Public hospital outpatient attendance – Public hospital emergency department attendance – Laboratory tests • Lost productivity of patients • Lost productivity of carers (non-patients) • Missed school days by pupils • Transport costs (to GP and hospital)
Direct intangible	• Health outcomes
Indirect tangible	• Costs for authorities dealing with the outbreak – Consulting fees for reviewing the events • Costs of the aftermath of the outbreak – Extra time spent by the PHU dealing with the outbreak (above normal hours) • Costs of managing water quality during the outbreak – Extra time spent boiling water
Indirect intangible	• Loss of faith in water quality

Source: LECG (2010), Scott et al. (2000), Cressey and Lake (2008).

3.3 A note on treatment of data

As part of this assignment, the Ministry of Health agreed to Sapere accessing health administrative data as part of the New Zealand Health Tracker directly using a dedicated PC in the Health and Disability Intelligence team in the Policy Business Unit. All NHIs were encrypted to ensure privacy but to allow linkage between datasets.

3.4 Estimating and valuing the costs

We sought to quantify and monetise costs wherever possible. In some cases, this was not possible and we resorted to alternative ways of measurement, or felt it was not appropriate to quantify the impact at all.

3.4.1 Direct health costs

Direct health costs are those incurred by patients, the health system, and the wider community (including those caring for sick people at home). All direct health costs, barring the over-the-counter pharmacy drugs, were estimated based on analysis of the New Zealand Health Tracker.

GP consultations

Data on actual GP consultations were not available for our study. We therefore constructed a proxy indicator from two data sources: the Primary Healthcare Organisation data mart and the Laboratory Testing Warehouse. We included all unique combinations of National Health Identifier (NHI) and GP visit date reported to these two data collections within our analytical time period. We then estimated how many of these visits were attributable to the outbreak by using a regression analysis to isolate how many consultations occurred over and above what would normally be expected over the period.

This gave us the number of consultations, to which we applied the dollar figures for co-payments and effective subsidies based on primary care Capitation Based Funding.

Community pharmacy OTC dispensing

We obtained data on the volumes and prices of sales of anti-diarrhoeal and oral rehydration medication sold by the single community pharmacy in the Town for the period t-43 until t+48 (including the month of the outbreak, the previous month and the consecutive month). Unlike the PHARMAC-subsidised drug price, where excess costs for all identified cases were represented, the community pharmacy OTC dispensing analysis only includes sales from the local pharmacy. This means it does not include costs related to sales for these products that occur outside the Town and hence will be an under estimate of the over the counter dispensing costs.

We fitted a regression model to this data to estimate the underlying trend in the mean sales, and then included an intervention effect for the month of the outbreak to estimate the additional expenditure on these products during the outbreak.

Community pharmaceutical dispensing

We also sought to estimate the cost of medications prescribed by GPs and dispensed by the Town's pharmacy. We used Community Pharmaceutical Dispensing Data from the

PHARMHOUSE.[12] This data records the dispensing of any drug subsidised by PHARMAC, as well as the subsidy cost of the drug and the patient co-payment.

We took all dispensing events for people with an NHI on the NHI denominator for the period June to October 2012 (the month of the outbreak and the two previous months, and then identified only those drugs dispensed to those people identified by the PHU as cases. We then used regression analysis to determine the underlying and intervention effects for this group (i.e. to estimate the co-payments and drug costs attributable to the outbreak).

Public hospital admissions

To estimate the costs of public hospital admissions, we looked at the following ICD-10 diagnosis codes,[13] in order to capture both campylobacter and its sequelae:

- A04.5 Campylobacter Enteritis
- K58 Irritable Bowel Syndrome
- M02 Reactive Arthritis, and
- G61.0 Guillain–Barré syndrome.

We used the cost weights for these diagnosis codes from the National Minimum dataset (NMDS) and the base price for the 2011/12 financial year provided by the Ministry of Health, to derive a cost weight price for each code.[14]

We then applied this price to the number of relevant cases identified in the discharge data from the NMDS. We reviewed all public discharge data for people with an NHI in the NHI denominator and an Area Unit (AU) that matched the study area (see 3.7 for an explanation of how the study population and area were defined).

Public hospital outpatient attendance

For outpatient events, we used data from the National Non-Admitted Patient Collection dataset (NNPAC), including those with an event type 'OP'. Very limited diagnostic information is available on this collection, making assignment of cause difficult. The collection has a Purchase Unit code and description that in general describes the services being purchased, a Health Speciality code that aligns with the department or speciality required to treat the individual and an accident flag denoting if the event was the result of an accident.

We reviewed all outpatient events for people with an NHI on the NHI denominator for the month of the outbreak and an AU in the study area. This involved looking through all events for individuals identified by the PHU.

---

12 The PHARMHOUSE warehouse, jointly owned by PHARMAC and the Ministry of Health contains records of all the claims for schedule subsidised medicines dispensed from community pharmacies within New Zealand.

13 ICD-10 International Classification of Diseases Version 10.

14 Weighted Inlier Equivalent Separations - http://www.health.govt.nz/nz-health-statistics/data-references/weighted-inlier-equivalent-separations

We then applied the National Price for 2012/13, for the purchase units for these events.

Public hospital emergency department attendance

We also used emergency department (ED) attendance data from the NNPAC held by the Ministry of Health, with an event type of 'ED'. As with the outpatient data, this has very limited diagnostic information available. Similarly, we applied the National Price for 2012/13, for the purchase units for these events.

Laboratory tests

To estimate the costs of laboratory testing of faecal samples, we obtained Community Laboratory testing data from the Laboratory Testing warehouse. This warehouse is used for financial purposes and does not contain records of the test results. It does however provide the date of sample collection, type of test and estimated price of the test. [15]

As for the pharmacy dispensing data, we selected all test events for people with an NHI on the NHI denominator for the period spanning the two months before the outbreak up to two months after the outbreak, and then identified only those tests associated with people identified as cases by the PHU. We then used a regression model to determine the underlying trend and intervention effect in total daily price of tests for this group (to estimate the additional test costs attributable to the outbreak).

3.4.2 Lost productivity of patients

We used the method referred to in LECG (2010) to estimate the cost of lost productivity of patients and their carers. For the cases that were identified we could see exactly how long they had symptoms and whether they worked or not. As the identified cases are partly those that went through the health services, we assumed that the unidentified cases were less sick than the identified cases, and that their symptoms did not last as long. We assumed that the unidentified cases had symptoms for 2.6 days on average. [16]

Then we estimated the proportion of this time that would have been spent on paid an unpaid work. We used the results of a survey done by Statistics New Zealand in 1999 on unpaid work to give us the ratio of paid to unpaid work. [17] Consistent with the LECG study, we used the national average value of this ratio, which states an average person aged over 15 spends 23.6 hours on paid work and 27.6 hours on unpaid work.

We then valued this lost productivity using the average hourly wage of 2011 ($24.78 per hour) for paid work and the minimum wage of $13.50 per hour for unpaid work.

---

15 Estimated price is used as many laboratories are funded through bulk-funded contracts. To estimate the price of a particular test type the total value ($) of the contract is divided by the contracted volume of tests.

16 This number is chosen such that the total average number of days of all cases, identified and unidentified, is equal to the average number of days of symptoms of 3.5.

17 http://www.stats.govt.nz/browse_for_stats/snapshots-of-nz/nz-in-profile-2012/earnings-from-wages-and-salaries.aspx

3.4.3 Lost productivity of carers

We also sought to estimate the lost productivity of people who spent time caring for children that became sick during the outbreak. When an adult needs to care for a child, it is likely that the chosen adult has a relatively low productivity, such as the stay-at-home parent if there is such a parent, a retired grandparent etc. The specific value of the productivity loss of the carer therefore depends on how elaborate the social network of the parents is, and how the distribution of productivity is within the household. We assumed that the average carer that stays at home to care for a sick child is half as productive as the average person is.

Caring for a sick child varies in intensity with the severity of the illness of the child. In most cases, the carer will still be able to do some productive work such as work from home, or contribute to the household. We assumed that the caring for a sick child consumes 50 per cent of a person's productive time on average.

We estimated this in the following way:

1. First, we calculated the total duration of symptoms in days for children between 0 and 17 years who were identified by the PHU as cases.

2. Then we took the number of identified child cases and multiplied this by the ratio of total estimated cases to identified cases that we determined earlier (see 2.5). This gave us an estimate of the total number of actual child cases.

3. Next, we applied our assumption (discussed above) of an average 2.6 days of symptoms for unidentified cases.

4. We then took the average values of paid and unpaid work discussed above, and halved this value to reflect our assumption of carers having 50 per cent of the productivity of the average person.

5. We then multiplied our figure of total hours spent by carers (the volume of lost productivity) by this price of productivity.

3.4.4 Missed days of school

We estimated the total number of school days missed by sick children. We did not seek to monetise these as we found no precedent in the literature for attributing an economic cost to missed days of school.

We estimated absenteeism due to sickness for the local pre-school, primary and secondary schools. As noted above, some local children attend schools outside of the area, so our figures may be under-estimates in this regard.

The Town's pre-school provided data on the number of days for which children were previously booked but did not attend due to sickness, for the five weeks encompassing the outbreak. Data were not provided by the pre-school for the period leading up to or following the outbreak, which made it difficult to estimate the days of absenteeism attributable to the outbreak. We assumed that the absenteeism in the first and last weeks on either side of the outbreak were reflective of the baseline absence due to sickness without the impact of the outbreak, and used the mean value of this as the baseline.

We submitted a request to the Ministry of Education to get school absence data for the seven schools located within the Study and Control areas (explained below) for the period starting two months before the outbreak up to two months after the outbreak. They provided data files for three of these schools, all of which are in the Study area. We found that one of the primary school files had absenteeism codes that could not be identified and was unusable. The schools that provided useable files were a high school in the Town and a primary school in the direct surroundings of the Town.

We only included absenteeism for doctors' visits, time spent in sickbay and sickness in our analysis. We converted these hours absent into days of absence.

Not having other data from schools in the Control area to baseline against, we took a conservative approach by fitting a regression line for the trend of the period and an intervention effect for the outbreak during August.

And as no other early childhood education (ECE) or school data was available, total ECE, primary and secondary school absenteeism was imputed based on the rates of absenteeism in the preschool and two schools data supplied and the numbers of children in the ECE, primary and secondary age groups in the study area.

3.4.5 Transport costs

We sought to estimate the costs to individuals for additional travel that they undertook to visit their GP or to go to hospital, as a result of the outbreak.

For GP visits, we took the average travel distance for probable and confirmed cases, by geo-coding the straight line distance in kilometres between the individuals' houses and their practice. We then multiplied this round trip distance by the number of probable and confirmed cases, as we know these people went to the GP. The average travel distance for confirmed or probable cases was used instead of actual travel distance, as it was not possible to identify the specific people who went to the GP because they were a case.

For hospital admissions, we calculated the travel distances between the Town and the City, and multiplying the round trip distance by the number of hospital admissions.

To estimate the price of this travel, we took the per kilometre running costs of a compact vehicle (under 1600cc), as published by the Automobile Association. We applied this price to the total number of kilometres travelled to produce an estimate of transport costs.

To estimate the price of air travel to another hospital in New Zealand we used the current return trip price on the Air New Zealand website for a Flexi Plus fare to the city in which the hospital was based.

3.4.6 Health outcomes

In quantifying the health outcomes due to the disease outbreak, we focussed on three categories of health outcome or disability states:

1. The estimated 359 milder cases that did not visit their GP (413 estimated cases less 54 cases known to have visited their GP);
2. The 54 more severe cases that visited their GP or were admitted to hospital; and
3. The one case with the moderately severe sequelae of GBS.

The majority of campylobacteriosis cases were likely from the Town on the basis that of the 138 confirmed or probable cases identified fitting the study case definition 94% came from the Town.

In health economics, outcomes are often expressed as the gain (or reduction) in quality and length of life, measured by quality adjusted life years (QALYs), or disability adjusted life years (DALYs). The DALY is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death, based on people's experienced burden of disease. One DALY is the equivalent of one year of healthy life lost, in the view of the average New Zealander.

As already stated for this study, we used three disability states to estimate the DALYs: one for milder disease with a weight of 0.067; one for more serious disease represented by a disability weight of 0.393 (Kemmeren, 2006); and a final state for sequelae, using the commensurate weights from Cressey (2009).

The calculation of the DALY is undertaken in two parts, the Years of Life Lost (YLL) and Years Lost to Disability (YLD), which are summed. The YLD was calculated by multiplying the duration by of symptoms by the disability weight and converting it into years.

There were no deaths resulting from this outbreak, so this cost was excluded from our analysis. Had there been fatalities, we could have either applied the YLL to the DALY calculation, or applied a 'statistical value of life' approach, both of which are supported by the literature.

3.4.7 Costs to authorities in dealing with the outbreak

The council of the district to which the Town belongs (the council) went to great efforts to contain the effects of the outbreak, and these efforts came at considerable cost. Efforts included the boil water notice, which involved the sending of letters to all households on the water main, once to inform the households of the boil water notice, and once to inform them that the boil water notice was lifted. The council also contacted various institutions by phone regarding the boil water notice, such as the schools and rest homes in the area. Council employees worked a sizeable amount of overtime.

The council is doing a costing study of its own and has agreed to forward us the report on the costs involved for the council in dealing with and managing of the outbreak. At the time of writing this report, however, we have not yet received this report so have not included these costs in our analysis.

We were however able to include the hours of overtime spent by PHU staff (as provided by PHU), valued at the average hourly wage rate.

In addition, the council contracted OPUS to do a study on the outbreak reviewing the events leading up to and including the outbreak, finding points of improvement in the procedures used. We included the direct cost of this study in our analysis.

3.4.8 Costs of the aftermath of the outbreak

The PHU spent time on dealing with the outbreak. Setting up a definition of symptoms, identifying the cases, and geographically mapping the first cases was crucial in realising the outbreak was happening. The PHU also spent time communicating with local primary care providers and council, and investigating the aftermath of the outbreak. Of course, this is part of the work of the public health unit, and as such not all work should be counted as extra costs due to the outbreak. We were informed however that staff worked overtime and took time in lieu as a result of the outbreak. We used these figures of time spent working beyond normal hours and applied the average hourly wage, to provide an estimate of these costs.

3.4.9 Costs of managing water quality during the outbreak

During the outbreak the consumers had to deal with managing the quality of the water they consumed and used. They were advised by the council to boil the water they used. Other efforts could have included purchasing bottled water to use instead of the tap water. We were unable to obtain sales data on the latter, but did acquire information on the boil water notices. We estimated the value of time spent boiling water, by households and the non-private dwellings in the area.

We focused on dwellings (rather than businesses or other institutions) in order to cover the population as a whole and thereby avoid double-counting (i.e. people who both live and work in the Town). We did not seek to adjust for the daily population exchange (for work and school, as discussed in 1.2).

For households, we first estimated the number of households in the area, by extrapolating 2006 Census data for subsequent population growth, and then calculating the average number of people per household.

The boil water notice was sent to private households on t+4. This means that it reached most people only on t+7. The lift of the boil water notice was sent in the same manner on t+8, which is expected to have reached most households on t+9 or t+10. We assume that private households have followed the boil water notice for an average of two days.

Based on estimates gathered in our interviews, we made an assumption that the average household spent on average 10 minutes a day on boiling water for consumption. We then applied the unpaid productivity rate of $13.24/hour to obtain a cost for the extra effort spent boiling water.

The 2006 census shows that there are up to three non-private dwellings in the area. We identified two of those as rest homes. We undertook interviews with the rest home managers to assess the amount of extra time that was spent by their employees to boil water for the use by both the clients and the employees. We then applied the average hourly wage rate to this time, to derive a cost for the time they spent boiling water during the outbreak.

Other efforts that were mentioned in our interviews included the use of water clearing pills, using a lot of disposable products for the period such as bibs, masks and aprons for the staff and a lot more washing than normally. The costs of these efforts were not quantified.

3.4.10 Loss of faith in water quality

Outbreaks such as this can lower the confidence of the public in the quality of the water supply also after the outbreak has ended. According to LECG (2010), loss of confidence in water supplies tends to be an issue after an outbreak has occurred and may lead to people avoiding consuming untreated or unboiled tap-water even after the all clear has been given.

Consumers may invest in point-of-use systems such as water filters, or respond to external information by precautionary boiling water even when it is not necessary, for example after heavy rainfall, or after information on outbreaks in other areas.

We sought to obtain qualitative information on behaviour change due to a loss of faith in the water quality, by interviewing a selection of locals.

We applied the average hourly wage to this anecdotal estimate of extra time spent managing water, to derive an estimate of the costs of this behaviour change. Because it is based on limited anecdotal information, we expect that this represents an underestimate of the total costs of loss in faith of water quality.

The following table summarises the units of measurement applied for each of these costs.

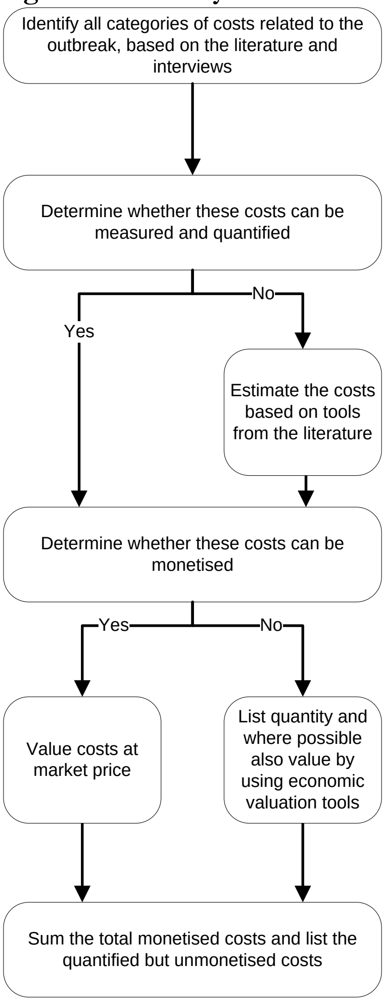
Table 3 Costing units

Type of cost	Unit of measurement
GP consultations	$ patient co-payment, and $ effective subsidy
OTC sales	Drug cost ($)
Public hospital admissions	Cost weight and medical and surgical cost weights per discharge ($)
Public hospital outpatient attendance	National price per purchase unit ($)
Public hospital emergency department attendance	National price per purchase unit ($)
Community pharmaceutical dispensing	$ patient co-payment and $ effective subsidy
Laboratory tests	Estimated price per test ($)
Lost productivity of patients	Value of days off work • Paid work (average hourly wages) • Unpaid work (valued at the minimum wage rate)
Missed school days by pupils	Number of days off school (unmonetised)
Transport costs	Cents per kilometres travelled / Price of airfares ($)
Health outcomes	Disability-adjusted life years (unmonetised)
Lost productivity of carers (non-patients)	Value of days off work • Paid work (valued at average hourly wages) • Unpaid work (valued at the minimum wage rate)
Consulting fees for reviewing the events	Price paid for consulting report ($)
Extra time spent by PHU dealing with the outbreak (above normal hours)	Price per hour of overtime worked/time in lieu taken ($)
Extra time spent boiling water	Cost per minute spent boiling water • Minimum wage rate for households • Average hourly wage rate for rest home workers
Loss of faith in water quality	Cost per minute spent boiling water (valued at average hourly wage rate)

3.5 Summary of our method

The following diagram summarises our overall approach to assessing the costs of the outbreak.

Figure 2 Summary of our method

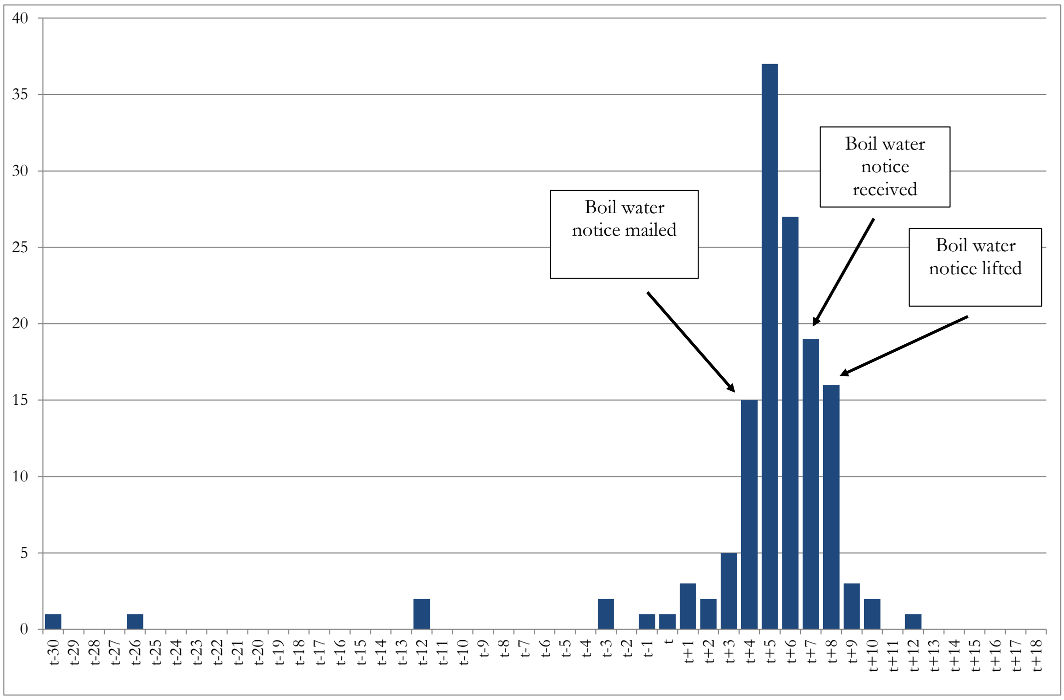


Source: Freely adapted from B. Baffoe-Bopnie et al. (2008) *Framework for operational cost benefit analysis in water supply*.

3.6 Choosing the time period for analysis

The case definition provided above has a time period of t-30 to t+17. This period was selected to account for any cases that may have been contracted prior to the contamination being detected through the routine weekly analysis, and for those who contracted the disease prior to the switch to the new water supply but whose symptoms persisted after this date. Confirmed cases were defined as being onset from t-1 until t+8, and probable cases as onset from t-30 until t+12.

Figure 3 Period for analysis
Chart shows number of cases



However to develop our cost estimates, we also needed to estimate a baseline before and after the outbreak. We therefore obtained data for longer time periods, to help us determine what the 'usual' levels of these variables would be, and therefore assess the marginal impact of the outbreak. The time periods for each of the data sets obtained are set out in Appendix 2.

3.7 Defining the population and area

Capitalising on the direct access to Ministry of Health administrative data through the New Zealand Health Tracker, a denominator population was constructed based on the NHI for people currently resident in the Town, the Control Town and their surrounds.[18] To ensure as little double counting of individuals as possible – through duplicates NHIs – we used the most recent reconciled master NHI (Dec 2012) across all datasets involving NHI linkages.

The denominator was based on people resident in the study area during the third quarter of 2012 with no date of death and an address in one of four Statistics New Zealand (SNZ) AUs. The areas included in the study were identified by their AU code, with one AU for the town areas of both the Town and the Control Town, and two further AUs for the area surrounding these towns.

18 The National Health Index (NHI) is the cornerstone of health information in New Zealand. It was established to provide a mechanism for uniquely identifying every healthcare user (HCU) by assigning each a unique number (known as the NHI number).

The population estimates from Statistics New Zealand (SNZ) and the NHI denominator are presented in Table 4. This shows for the study areas we have very similar counts between the SNZ estimates and the NHI denominator. For the control areas, the differences between the NHI denominator and the SN estimates are more substantial per AU. However, the numbers for the total control area are close. And the total population of the case area and the control area vary minimally.

Table 4 Case and control area units and populations 2012

Area	Area Unit Name (code)	SNZ (n)	NHI (n)	Concordance (%)
Case Town	the Town (586900)	1,000-2,000	1,000-2,000	-2%
Case Surrounds	Neighbouring community (587010)	3,000-4,000	3,000-4,000	+4%
Case		**5,000-6,000**	**5,000-6,000**	**+2%**
Control Town	the Control Town (597300)	1,000-2,000	1,000-2,000	+24%
Control Surrounds	Surrounds of Control Town (597506)	3,000-4,000	3,000-4,000	-7%
Control		**5,000-6,000**	**5,000-6,000**	**+1%**
Difference between Case and Control		50	10	
All		10,000-11,000	10,000-11,000	+2%

Source: Statistics New Zealand Population Estimates 2012 and Ministry of Health Administrative Data.

4. Analysis and results

4.1 Central estimates

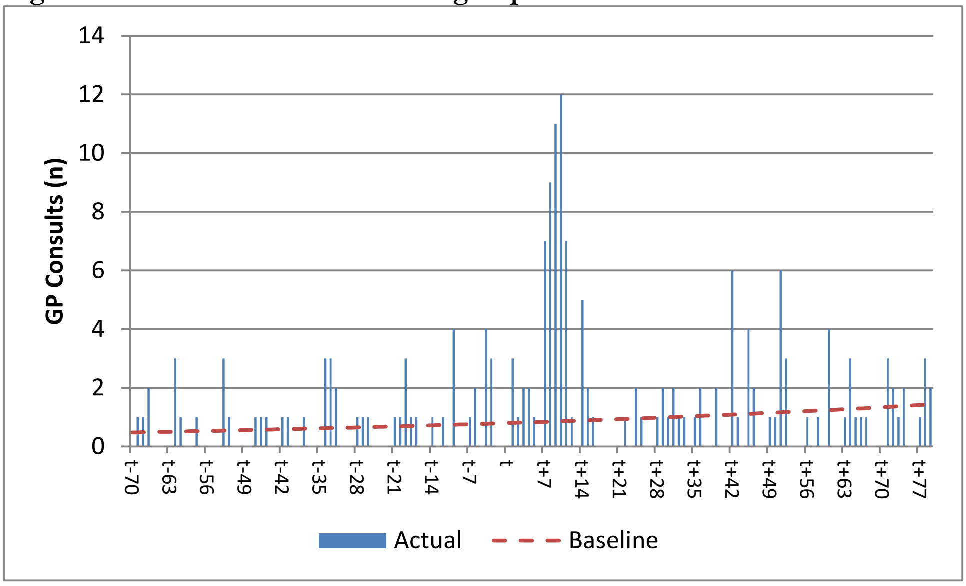
4.1.1 Direct health costs ($191,162)

GP consultations ($3,618)

Figure 4 presents the total GP consults per day for the case group, as identified by the PHU. It shows that the case group as a whole has low GP consults counts per day for all months except for the month of the outbreak, where the numbers of consults are higher, and peak in the weeks following date t.

The regression analysis predicted that 54 GP consults were attributable to the intervention effect in the model. Assuming a patient co-payment of $36 for each consult and an effective subsidy of $31 for each consult under primary care Capitation Based Funding (CBF), total costs attributable to the outbreak were $1,944 for patient co-payment and $1,674 for the CBF subsidy.

Figure 4 GP Consults for PHU case group

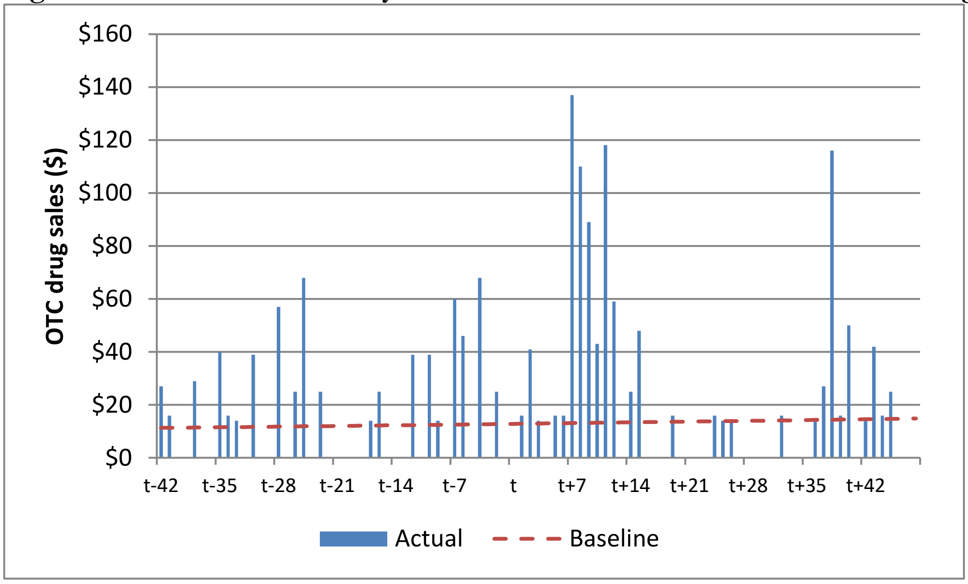


Source: PHO data mart and Laboratory Testing warehouse, Sapere analysis.

Community pharmacy OTC dispensing ($621)

The regression analysis estimated an additional $621 of sales of anti-diarrhoea and rehydration products during August, which have been attributed to the outbreak.

Figure 5 The Town's Pharmacy Over-the-Counter sales of anti-diarrhoeal drugs



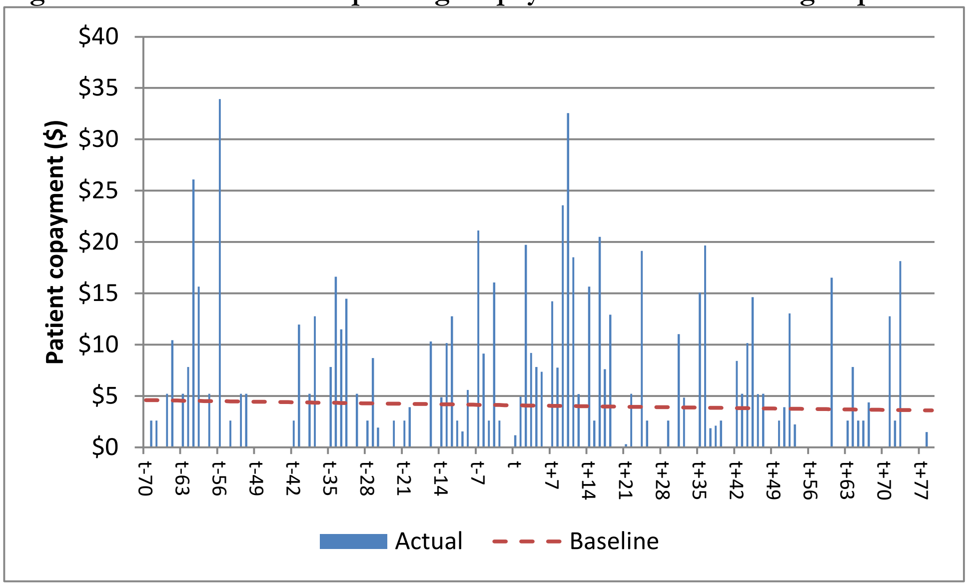
Source: the Town's Pharmacy, Sapere analysis.

Community pharmaceutical dispensing ($199 drug cost + $159 patient co-payment)

Figure 7 shows total patient prescription co-payments per day for the case group identified by the PHU. It shows days of the week where co-payments cluster at higher levels, and peaks in mid-June and late August.

Our regression analysis predicted that $159 of the co-payment for the month of the outbreak was attributable to the outbreak.

Figure 6 Pharmaceutical dispensing co-payments for PHU case group

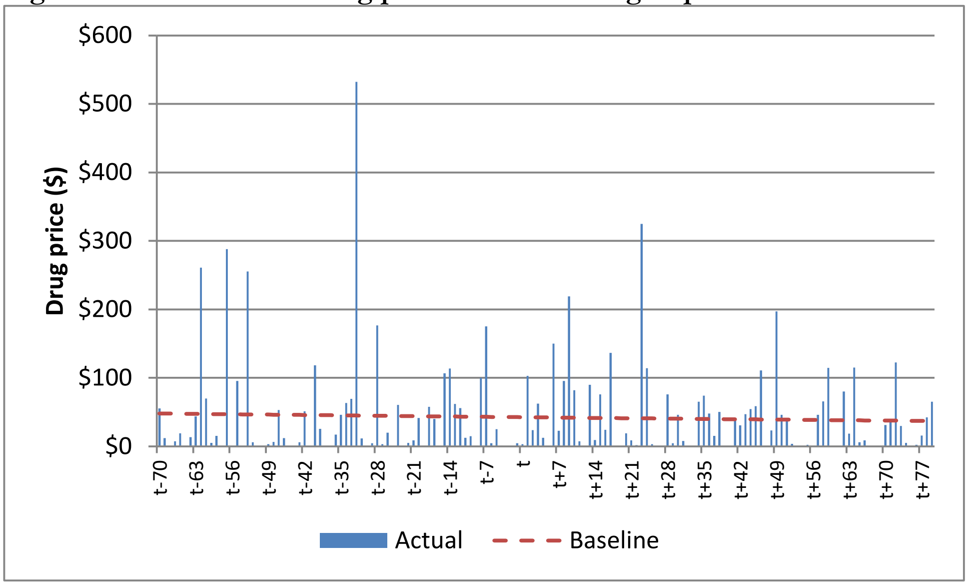


Source: PHARMHOUSE, Sapere analysis.

Figure 7 shows total spend on drugs per day for the case group identified by the PHU. The figure does not show an obvious increase in drug spending in the month of the outbreak, nor do peaks in drug price occur in the two weeks following date t. If anything, an increase in drug spending occurs around t-60, with a spike on t-32.

The regression analysis predicted that the outbreak was associated with a $199 additional total drug cost in the month of the outbreak compared to the other months.

Figure 7 Pharmaceutical drug price for PHU case group



Source: PHARMHOUSE, Sapere analysis.

Public hospital admissions ($2,636 + $181,815 for GBS case)

We identified two admissions to public hospital with a diagnosis code of A04.5 (campylobacter enteritis). Both were two individuals already identified by PHU as cases and both occurred in the month of the outbreak. The first admission event was for a person with a primary diagnosis of A04.5 and the second admission was for a person who had a primary diagnosis of J22 (unspecified acute lower respiratory infection) and A04.5 as a second diagnosis.

The first event had a WIES cost weight of 0.474 and the second a cost weight of 0.398. Based on the assumption that the secondary diagnosis of campylobacter in the second event would have contributed to the admission to hospital and hence the cost, we assigned half of the cost of the admission was attributed to campylobacter. This gave us a total attributable cost weight of 0.673.

The base price for a cost weight in 2012/13 was $4,614.36, giving a total price of $3,105. After subtracting the price for the component relating to ED attendances for these events ($469) the total attributable price was $2,636.

In terms of sequelae, we identified two public hospital events for the same individual, both with a primary diagnosis of G61.0 (GBS) in the month following the outbreak. These two events were directly sequential, meaning that the individual was most likely transported from one hospital to another. The individual did not have any diagnosis of A04.5 in the hospital data since their birth, was not identified by the PHU and had not been diagnosed with GBS in the hospital data prior to the outbreak. The cost weights for these two events were 37.88 and 1.522 and factoring the cost weight base price of $4,614.36 this amounts to a total $181,815. Our analysis of this event is explained in more detail in Appendix 3.

Apart from this one case of GBS, no other possible sequelae were identified in the four months of hospital data reviewed.

Public hospital outpatient attendance ($0)

We identified three outpatient attendances but all were for services not related to infectious diseases. There was therefore no outpatient cost attributable to the outbreak.

Public hospital emergency department attendance ($469)

Two ED attendances were identified and had been coded as ending with admission to hospital. These were for the same two people identified in the public hospital admissions data. The ED attendance dates also coincided with the hospital admission dates and were deemed to be the initiating events for the hospital admissions.

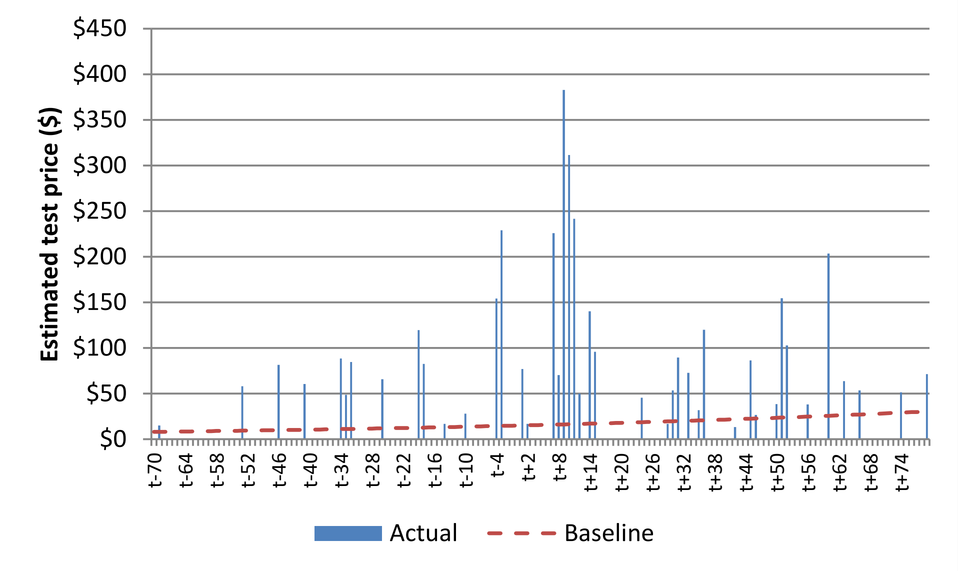
The National Price in 2012/13 for the purchase unit for each of these two events was $312.46. Assuming, as with the public hospital discharges, half the cost of the second event was attributed to the outbreak, we estimated the total cost at $469.

Laboratory tests ($1,645)

Figure 8 presents the total test price per day for the case group identified by the PHU. It shows that the case group as a whole have testing costs each day throughout the period. In the month of the outbreak, where the per day price of tests for the group are higher, peaking in the two weeks following date t (corresponding with the most frequent onsets). There is also evidence of a gradual upward trend in per day test costs for the period.

Our regression analysis predicted that $1,645 of the total laboratory test price for the month of the outbreak was attributable to the outbreak. It should be noted that a significant proportion of this was due testing for enteric disease and giardia, which is not unexpected with acute gastrointestinal symptoms caused by campylobacter.

Figure 8 Total laboratory test price for PHU case group



Source: Laboratory testing warehouse, Sapere analysis.

4.1.2 Lost productivity of patients ($126,474)

The 138 confirmed and probable cases identified by the PHU had a total of 734 days of symptoms with a maximum of 28 days, a minimum of one day and a mean of 5.3 days. We used the 87 cases identified to be aged 15 and over to estimate productivity loss. These cases had a total of 475 days of symptoms with a maximum of 28 days, a minimum of one day and a mean of 5.5 days. For the 275 unidentified cases, we assumed the age distribution to be the same as for the identified cases, which gave us an estimated 173 cases of 15+.

Applying the assumptions discussed in the previous chapter for length of time off work and value of this time, we arrived at a total estimate of lost productivity of patients of $126,474.

We compared our estimates to the prediction of CBA literature on missed productivity and found that our estimate is less than half of the productivity assumed in other studies. The estimates in the literature result in a total productivity loss of $239,793, but assume productivity losses for children under the age of 15 years (which we do not).[19] [20]

We stand by our estimate, as it is based on the data of the specific cases that were identified, but we realise that it should be seen as a modest estimate of the total productivity loss.

4.1.3 Lost productivity of carers ($30,183)

For the 62 children (0-17 years) identified as cases by the PHU, the total duration of symptoms was 309 days or 44.1 weeks. Applying the method outlined above to account for unidentified cases produced an estimate of 90.1 weeks in total spent caring for child patients.

[19] The average value of $957.41/week is used, as discussed above.

[20] According to LECG (2010), Cressey and Lake (2008), Cressey and Lake (2007).

Multiplied by the assumed price of this time gave us a value for carers' loss of productivity of $21,566.

By comparison, a 2007 UK study (Loregelly et al. 2008) found that parents of children age 0-5 years with gastrointestinal disease (not Rotavirus but otherwise unspecified) had to take 2.34 days on average off work due to their child's illness. Using the estimate of 124 incident cases in children for the Town's outbreak and assuming an eight hour working day, this translates to 2,321.3 hours of lost work for parents (at $24.87). This alternate estimate of carer work productivity loss is $57,521, which is nearly three times higher than our first estimate. It is based on the responses of parents of young children (aged 0-5 years), who will be provided with more and longer care from only their parents compared with older children and hence is likely an over-estimate.

For the one case hospitalised of GBS and due to the severity of the condition and length of hospital stay (2 months), we assume that at least one relative or support person was regularly present with the individual in the hospital and hence lost their full productivity during the individual's stay in hospital.

We can only assume that after the hospital stay the individual was at home still needing care. However, we have no information on the length of illness of the individual after the hospital stay, so we are only estimating the lost productivity of the support person during the hospital stay.

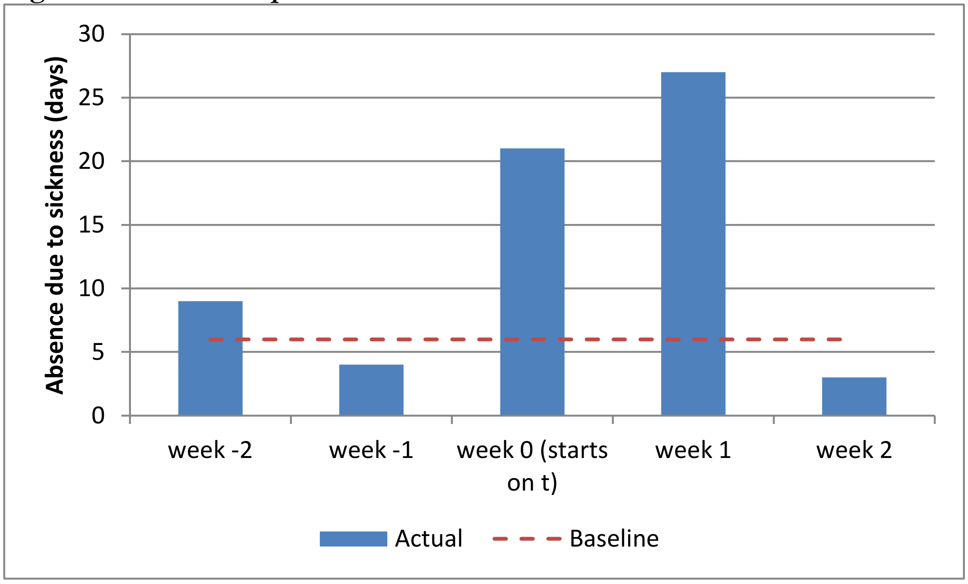
Therefore, the cost of lost productivity of support person for this case is for 9 weeks (from t+29 until t+91). Valued at the average value for weekly productivity of $957.41 this adds up to $8,617.

4.1.4 Missed days of school (871 days)

Pre-school absences
As can be seen in Figure 9, absenteeism from the Town's pre-school was highest in the two weeks following date t, coinciding with the peak in incident cases identified by PHU.

Assuming that the absenteeism in the weeks on either side of this period is reflective of the baseline absence due to sickness without the impact of the outbreak, we calculated a value of 6 days as the mean baseline. Subtracting 6 days from each weekly value and summing across weeks, the pre-school absence due to the outbreak is estimated at 34 days. The Town's pre-school has 49 children enrolled giving a mean absence per student due to the outbreak of 0.69 days (34/49).

Figure 9 The Town's pre-school absences due to sickness



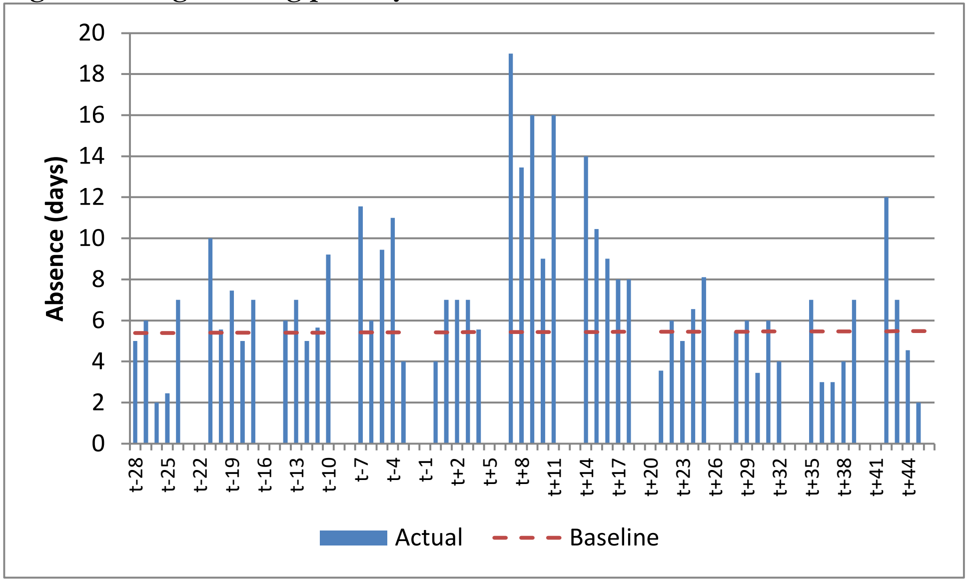
Source: the Town's pre-school, Sapere analysis.

Primary and secondary school absences

Days absent from the neighbouring primary school are presented in Figure 10. A total of 389 days of absence due to sickness from school were recorded during the period, which included 55 days at school. There were higher levels of school absenteeism in the weeks after date t, when the majority of cases were identified.

Our regression estimated 91 additional days of school absenteeism due to the outbreak and a maximum of 14 days of absence on any given day in that week, taken to represent the likely maximum of students who were sick due to the outbreak in the year 0 to 7 group (5 to 12 years old). This results in an estimate of 0.68 days (91/133) as the mean days of absence per student due to the outbreak.

Figure 10 Neighbouring primary school absences due to sickness

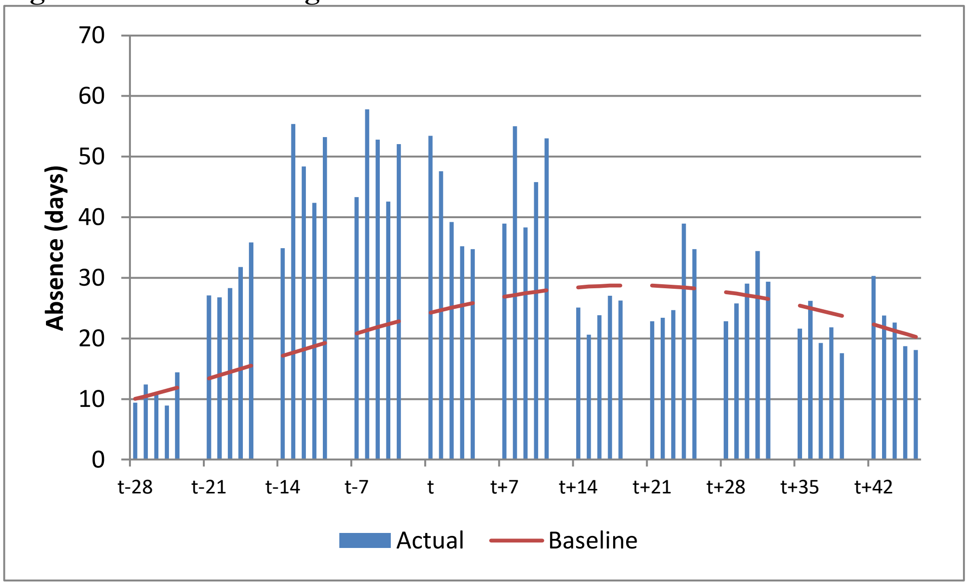


Source: Neighbouring primary school Sapere analysis.

Days absent from the Town's high school are presented in Figure 10. A total of 1,759 days of absence due to sickness from school were recorded during the period, which included 55 days at schools. There were higher levels of school absenteeism in the weeks running from t-21 to date t, prior to when the majority of cases were identified.

Our regression estimated 386 additional days of school absenteeism due to the outbreak and a maximum of 36 days of absence on any given day in that week, taken to represent the likely maximum of students who were sick due to the outbreak in the year 8 to 13 group (13 to 18 years old). This results in an estimate of 0.52 days (386/736) as the mean days of absence per student due to the outbreak.

Figure 11 The Town's high school absences due to sickness



Source: The Town's high school, Sapere analysis.

The NHI denominator derived identified 337 children in the 0-4 year age group, 573 children in the 5-12 age group and 467 children in the 13-18 year age group in the study area. Taking the product of mean days absence with the number of students in each category gave us estimates of total days absent of 234 days for ECE, 392 days for primary school and 245 days for secondary school.

The total estimate for secondary schools is well below the 386 days absence estimated for the Town's high school, most likely due to the fact that the Town's high school draws its roll beyond the Town's immediate surrounds. There was also some anecdotal evidence that the higher than usual absences prior to date t could be driven by seasonal influenza. The lower secondary school figure has been used given the uncertainty of the drivers and in order to remain cautious.

4.1.5 Transport costs ($1,690)

The average travel distance to GP visits for the 138 individuals in the case group was 5 km with a maximum of 43km and a minimum of 0.2km. One average round trip would cover 9km for the 54 additional GP consultations, hence the total additional travel required would be 486km. The estimated travel distances for the three hospital admissions in the City were 276km, giving a total overall of 752km. Return air travel for the individual with GBS that hospitalised in another city was priced at $608 and a similar amount for a relative or support person to accompany the individual was included.

Applying the running costs for local travel distances, combined with the cost of air travel produced total transport costs of $1,690.

4.1.6 Health outcomes (1.087 loss in DALYs)

Using the estimate of the total incident cases of 413 and the 54 more serious cases seeing a GP, the difference of 359 represents the remaining, milder cases. For 84 of these the total duration of symptoms of 275 was recorded in the PHU records of identified cases. For these 275 incident cases, the assumption that an average of 3.5 days of symptoms was made, giving a total of 963 days of symptoms.

A DALY for the case of GBS was also included based on it being a moderately serious case (F4) with consequences lasting one year, using the newer value from Cressey (2009) of 0.367. We think this is a moderate estimate given the length of the hospital stay and the age of the individual.

The breakdown of the DALY calculation for incident cases attributable to the outbreak is presented in Table 5. A total of 0.72 DALYS are attributed to the outbreak.

Table 5 Estimated Disability Adjusted Life Years

Source	Cases	Unit of Measure	Units	Disability Weight[21]	DALY
Disability Loss Serious (Confirmed/Probable)	54	Days (visiting a GP or Hospitalised)	459	0.393	0.49
Disability Loss Mild (Confirmed/Probable)	84	Days (not visiting a GP)	275	0.067	0.05
Disability Loss Mild (Estimated)	275	Days (not visiting a GP)	963	0.067	0.18
Guillain-Barré syndrome (F04)	1	Year	1	0.367	0.367
Total DALYs					**1.087**

Source: Local Public Health Unit, Sapere analysis.

4.1.7 Costs to authorities in dealing with the outbreak ($45,000)

The cost of the OPUS study, which was commissioned by the council, was $45,000.

4.1.8 Costs of the aftermath of the outbreak ($1,115)

We were informed by the PHU that about 20-25 hours of overtime were worked on the outbreak, and also 20-25 hours of time in lieu were taken. This means that about 45 hours of extra work was spent on the outbreak above and beyond the normal working hours of the public health unit. Priced at $24.78/hour for paid work this adds up to $1,115.

4.1.9 Costs of managing water quality during the outbreak ($9,743)

We estimated that households spent 642 hours and 20 minutes on boiling water, which was valued at a cost of $8,504.

[21] http://www.rivm.nl/bibliotheek/rapporten/330080001.pdf

In terms of the rest homes, one manager told us that their rest home had seven patients and nine staff, and spent an estimated two hours of work a day on boiling water. The second rest home had 28 clients at the time of the outbreak and 20 staff. The boil water notice meant for this rest home that there was constantly one staff in the kitchen boiling pots of water 24 hours a day. However, this person could also do other work in the kitchen on the side, and therefore we have allotted only a third of that time to the effort of boiling water, which totals to 8 hours of extra work per day.

This added up to a total of 5 days that all water was boiled, which we valued at $1,239.

4.1.10 Loss of faith in water quality ($694)

One of the rest homes in the Town's area informed us that after the outbreak they reacted to information on outbreaks in other surrounding areas by boiling their water before consumption, out of precaution. Another rest home in the area is investing in filtration and storage systems so as to not be dependent on the local water supply at all for their water consumption.

In the case of the first rest home, the manager expressed that this was a clear result of the outbreak we are discussing in this report, and had resulted in the 6 months following the outbreak in two periods in which all water was boiled before consumption and oral use (such as brushing teeth). The first period was for the seven days after the boil water notice was lifted, out of precaution. The second period was during an outbreak in a nearby area. There is no information on how long they boiled their tap water in this period. To err on the safe side, we assumed that this was shorter than during the outbreak we are reporting on and we used a total estimate of seven days. The cost this involves is the work of one employee having to boil water for the consumption and use of 7 patients and 9 staff. This amounts to an estimated two hours of work a day for every day the water is boiled. This amounts to a total of 14 hours of extra work due to the lower faith in water quality in this rest home.

In the case of the second rest home, it was explained that the investments to achieve independence from the local water supply were already considered and initiated before the 2012 outbreak. Although the lower confidence in the drinking water quality is influenced by outbreaks such as these in the past, these actions cannot be attributed to the 2012 outbreak that this report deals with.

4.2 Total costs

The following diagrams set out the total estimated costs of the outbreak. Figure 12 shows the total costs broken down in direct/indirect and tangible/intangible. Figure 13 shows the same costs but in an alternative classification, showing the division of the costs between the government and the public.

Figure 12 Total estimated costs of the outbreak

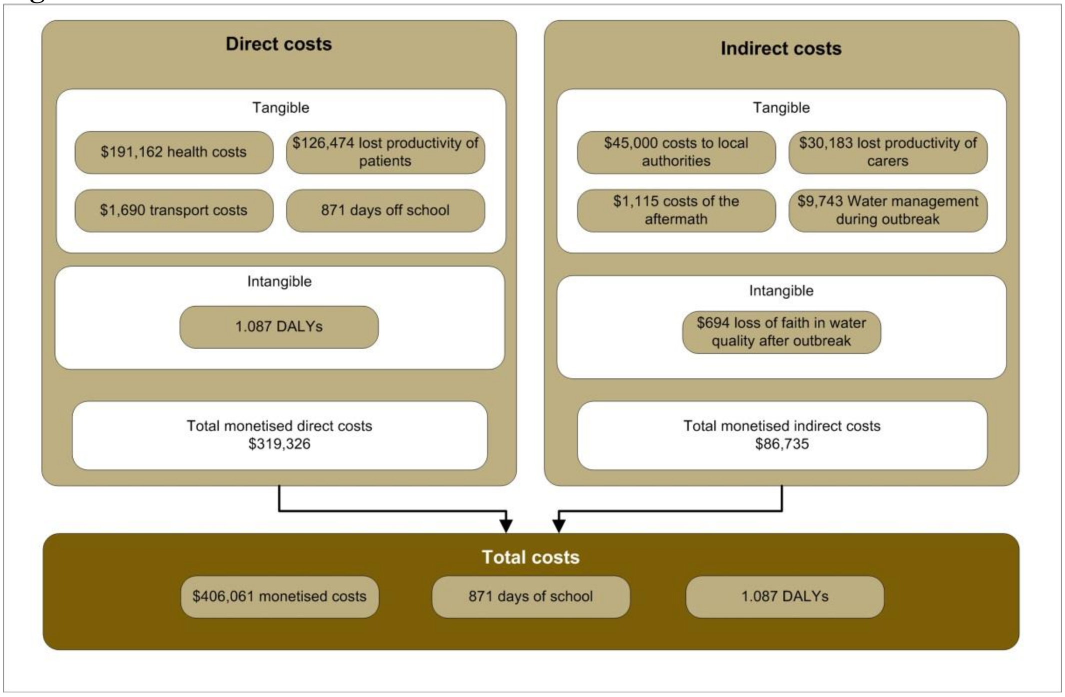
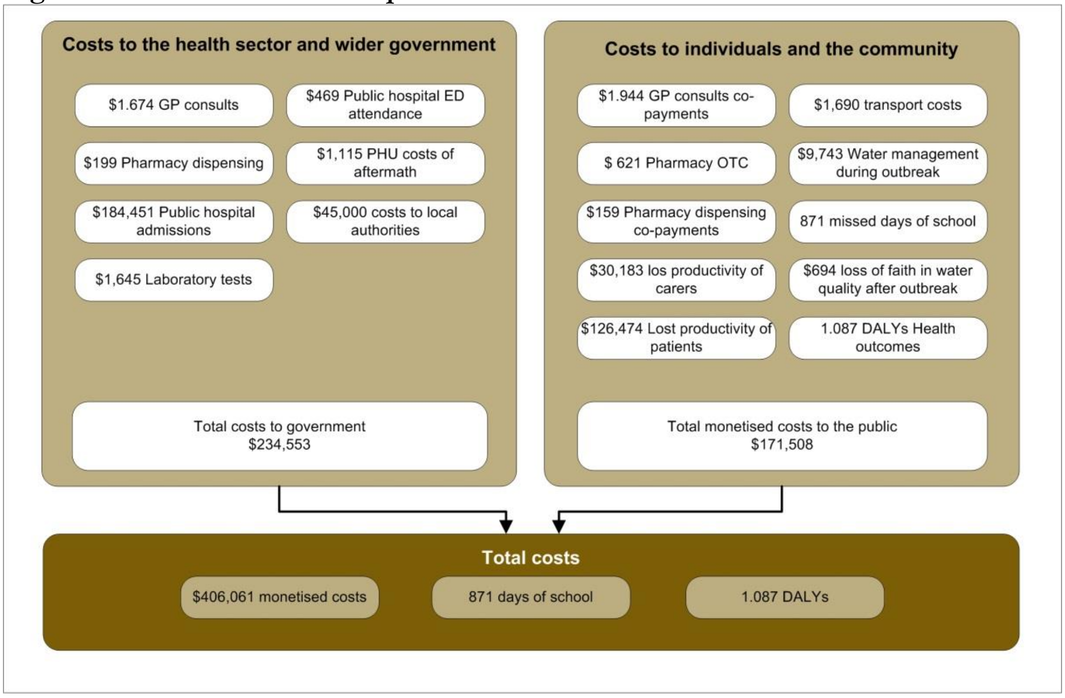


Figure 13 Break-down of costs per cost bearer



4.3 Caveats and limitations

Although we have gone to great lengths to provide an overview of cost that is as all-encompassing as possible, it is important to acknowledge the shortcomings and limitations of our results.

The first limitation of our results regards health costs. In the health data, we have only identified costs made for individuals living in the area. This excludes children that live outside the area, but that go to school in the Town. These children would still drink the water from the taps while they are at school, and hence could have gotten infected. Based on what we are told by locals, the number of children that fall into this category is relatively low. The same goes for people living outside the area but working in the area, or the people who were passing through during the outbreak. Due to this factor, it is possible that we have missed a few cases and have not taken the health costs of these cases into account. Also, the productivity losses of these people, or the people taking care of these sick children, were not taken into account.

When it comes to days of school that were missed, this works the other way around. As we have only included absenteeism at the schools in the Town's area, this means we have not taken into account those children that live in the Town, but go to school outside the area, for instance in the City. This means that there might be an underestimation of the total number of days of school that were missed.

Another cost we did not include was the workload at the general practice. During the outbreak, the practice was overrun with phone calls and patients seeking consultations. Throughout this time, the GPs and the nurses even more had a workload that was larger than normal. This resulted in other work that had to be put off or postponed. Other patients might have had to wait longer than normal to get a consultation with their GP. But due to the lack of measures or robust estimates, these costs have not been included in this report.

Due to these limitations we are aware that the total costs as presented in this report might underestimate the actual costs. However, we believe that this report provides a solid estimate of the minimal costs that were involved. As such, this report can be used as a guideline of what costs can be expected from similar outbreaks in the future.

4.4 Sensitivity analysis

We undertook a sensitivity analysis to determine the likely upper and lower limits in our cost estimates. We did this by recalculating all the cost estimates based on the lowest and highest plausible estimates of campylobacteriosis cases using the available literature. The sensitivity was based only on the one variable as most other variables were well estimated and the number of cases had the most substantive effect on cost estimates. The plausible range was from 158 to 754 campylobacteriosis cases (Table 1). The highest estimate in the table of 2,416 cases was excluded as a plausible option as it was based on the number of positive faecal test results and the local practice stopped testing partway through the outbreak, which would bias this estimate.

The total monetised costs and DALYs were relatively straightforward to calculate as they involved the same calculation methods described previously and only varied in the case of lost productivity of cases, lost productivity of carers and DALYs.

Days off school were unaffected by the number of cases due to the way they were calculated. We estimated average days off school per child in the school population for the schools we had data for. These averages were then applied to the school populations in the schools we did not have data for.

Table 6 presents the sensitivity of costs to uncertainty in the number of campylobacteriosis cases.

Table 6 Sensitivity analysis of costs estimates, with varying number of cases

	Low	Best	High
Cost	$308,592	$406,061	$536,401
School days	871	871	871
DALYs	0.925	1.087	1.307
Cases of campylobacteriosis	158	413	754

Source: Sapere analysis.

Another factor of uncertainty is added by the GBS case. Although it is highly likely that the GBS case can be attributed to the outbreak, a sensitivity analysis can be done to estimate the costs if this outbreak had not led to a GBS case. For the same reasons as before the number of school days missed that can be attributed to the outbreak does not change. However, if the GBS case were not to be attributed to the outbreak, this would lower both the costs and the DALYs considerably.

Table 7 Sensitivity analysis of costs estimates, with and without a GBS case

	No GBS	Best (1 GBS)
Cost	$214,413	$406,061
School days	871	871
DALYs	0.72	1.087
Cases of campylobacteriosis	413	413

Source: Sapere analysis

Appendix 1 References

Abelson, P., Potter Forbes, M., and Hall, G. (2006). *The annual cost of food-borne illness in Australia*: Australian Government Department of Health and Ageing.

Adamowicz, V., Dupont, D., and Krupnick, A. (2005). *Willingness to Pay to Reduce Community Health Risks from Municipal Drinking Water: A Stated Preference Study*. Retrieved from http://www.webmeets.com/files/papers/ERE/WC3/187/Adamowicz%20Dupont%20Krupnick%20Water%20Kyoto%20Submission%20Dec%202005.pdf

Adlam, B., Perera, S., Lake, R., Williman, J., Gallagher, L., and Bhattacharya, A. (2009). *Acute Gastrointestinal Illness (AGI) Study: Community Survey*: ESR.

Baffoe-Bonnie, B., Harle, T., Glennie, E., Dillon, G., and Sjovold, F. (2008). *Framework for Operational Cost Benefit Analysis in Water Supply*.

Bailie, R.S., B. E. Carson and A.L. McDonald (2004), 'Water supply and sanitation in remote Indigenous communities – priorities for health development', *Australian and New Zealand Journal of Public Health*, 28:5, pp. 409-414.

Ball, A. (2006). *Estimation of the Burden of Water-Borne disease in New Zealand: Interim report.* Wellington: Ministry of Health.

Brunkard, J. M., Ailes, E., Roberts, V. A., Hill, V., Hilborn, E. D., Craun, G. F., et al. (2011). Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water – United States, 2007-2008. *Morbidity and Mortality Weekly Report Surveillance Summaries, 60*(ss12), 38-68. Retrieved from http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6012a4.htm?s_cid=ss6012a4_w

Chiò, A., Cocito, D., Leono, M., Giordana, M. T., Mora, G., Mutani, R., and the Piemonte and Valle d'Aosta Register for Guillain-Barré Syndrome. (2003). A prospective, population-based incidence and outcome survey. *Neurology, 60*(1), 1146-1150.

Corso, P. S., Kramer, M. H., Blair, K. A., Addiss, D. G., Davis, J. P., and Haddix, A. C. (2003). Cost of Illness in the 1993 Waterborne *Cryptosporidium* Outbreak, Milwaukee, Wisconsin. *Emerging Infectious Diseases, 9*(4), 426-431.

Cressey, P., and Lake, R. (2007). *Risk Ranking: Estimates of the burden of food-borne disease for New Zealand*: ESR.

Cressey, P., and Lake, R. (2008). *Risk Ranking: Estimates of the cost of food-borne disease for New Zealand*: Institute of Environmental Science and Research Limited

Dale, K., M. Kirk, M. Sinclair, R. Hall and K.Leder (2010) 'Reported waterborne outbreaks of gastrointestinal disease in Australia are predominantly associated with recreational exposure', *Australian and New Zealand Journal of Public Health*, Vol 34:5, pp. 527-530.

Department of Human Services, State Government of Victoria. (2004). Drinking Water Quality Regulatory Framework for Victoria, Regulatory Impact Statement for the Safe

Drinking Water Regulations 2004. Retrieved from http://www.vcec.vic.gov.au/CA256EAF001C7B21/WebObj/sdwr-ris/$File/sdwr%20-%20ris.pdf

Fairley, C., Sinclair, M., and Rizak, S. (1999). Monitoring not the answer to cryptosporidium in water. *The Lancet, 354*, 967-969.

Gearry RB, Richardson A, Frampton CMA, Collett JA, Burt MJ, Chapman BA, Barclay ML. (2006) High incidence of Crohn's disease in Canterbury, New Zealand: Results of an epidemiologic study. *Inflammatory Bowel Diseases*; 12: 936-943.

Hasler, B., Lundhede, T., Martinsen, L., Neye, S., and Schou, J. S. (2005). *Valuation of groundwater protection versus water treatment in Denmark by Choice Experiments and Contingent Valuation*: National Environmental Research Institute.

Hellard, M., Sinclair, M., Fairley, C., Harris, A., and Kirk, M. (2003). Economic evaluation of community gastroenteristic [Electronic Version]. *Journal of Gastroenterology and Hepatology* 18, 322-328.

Hellard, M. E., Sinclair, M. I., Forbes, A. B., and Fairley, C. K. (2001). A Randomized, Blinded, Controlled Trial Investigating the Gastrointestinal Health Effects of Drinking Water Quality. *Environmental Health Perspectives, 109*(8), 773-778.

Hopkins, R. S., Gaspard, B, Williams Jr, F. P., Karlin, J.K., Cucor, G., and Blacklow, N. R. A Community Waterborne Gastroenteritis Outbreak: Evidence for Rotavirus as the Agent. *AJPH, March 1984*, *74*(3), 263-264.

Hoxie, N. J., David, J. P., Vergeront, J. M., Nashold, R. D., and Blair, K. A. (1997). *American Journal of Public Health, 87*(12), 2032-2035.

Hrudey, S. E., Payment, P., Huck, P. M., Gillham, R. W., and Hrudey, E. J. (2003). A fatal waterborne disease epidemic in Walkerton, Ontario: comparison with other waterborne outbreaks in the developed world. *Water Science and Technology, 47*(No 3), 7-14.

Hunter, P., Pond, K., Jagals, P., and Cameron, J. (2009). An assessment of the costs and benefits of interventions aimed at improving rural community water supplies in developed countries. *Science of the Total Environment* (2 April 2009).

Hutton, G., and Haller, L. (2004). Evaluation of the Costs and Benefits of Water and Sanitisation Improvements at the Global Level. Geneva: Water, Sanitation and Health; Protection of the Human Environment; World Health Organisation.

Kemmeren, J. M., Mangen, J-J., van Duynhoven, Y. T. H. P., and Havelaar, A. H. (2006).*Priority setting of food-borne pathogens. Disease burden and costs of selected enteric pathogens.* Netherlands: Author. Retrieved from http://www.rivm.nl/bibliotheek/rapporten/330080001.pdf

Kemmeren, J. M., Mangen, M. J. J., van Duynhoven, Y. T. H. P., Havelaar, A. H. (2006). *Priority setting of food-borne pathogens; Disease burden and costs of selected enteric pathogens*: National Institute for Public Health and the Environment, Netherlands

King, N., Lake, Rob, Sexton, Kerry, and Bridgewater, Philippa. (2007). *Acute Gastrointestinal Illness Study: Laboratory Survey*: ESR.

Kukkula, M., Maunula, L., Silvennoinin, E., and von Bonsdorff, C. H. (1999). Outbreak of viral gastroenteritis due to drinking water contaminated by Norwalk-like viruses. *The Journal of Infectious Diseases, 180*(6), 1771-1776.

Kuwabara S., Ogawara, K., Misawa S., Koga, M., Hiraga, A., Kanesaka, et al. (2004). Does *Campylobacter jejuni* infection elicit "demyelinating" Guillain-Barré syndrome? *Neurology, 63*(3), 529-533.

Lake, D. R., Adlam, D. B., and Perera, D. S. (2009). *Acute Gastrointestinal Illness (AGI) study: Final study report.* Wellington: ESR.

Lake, R. J., Baker, M. G., Garrett, N., Scott, W. G., and Scott, H. M. (2000). Infectious Special II: Campylobacter to the Common Cold. *The New Zealand Medical Journal, 113*, 278-281.

Laursen, E., Mygind, O., Rasmussen, B., Rønne, T. (1993). Gastroenteritis: a waterborne outbreak affecting 1600 people in a small Danish town. *Journal of Epidemiology and Community Health, 1994*(48), 453-458.

Levin, R., Harrington, W. (1995) Infectious waterborne disease and disinfection by-products in the US: costs of disease. IAHS publication, 233; pp. 305-307.

Livernois, J. (2002). *The Walkerton Inquiry. Value of life estimates in an economic cost assessment*. Toronto.

Livernois, J. (2001). The Economic Costs of the Walkerton Water Crisis.

Lorgelly, P.K., Joshi, D, Iturriza Go´mara, M, Flood, C, Hughes, C. A., Dalrymple, J, Gray, J, Mugford, J. (2008) Infantile gastroenteritis in the community: a cost-of-illness study. *Epidemiol. Infect*, 136, 34-43.

MacKenzie, W. R., Hoxie, N. J., Proctor, M. E., Gradus, M. S., Blair, K. A., Peterson, D. E., et al. (1994). A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the public water supply. *The New England Journal of Medicine, 331*(3), 161-167.

Majowicz, S. E., McNab, W.B, Sockett, P, Henson, K, Dore, K, Edge, V.L, Buffett, M.C, Fazil, A, Read, S, McEwan, Stacehy, D, Wilson, J.B. (2005). Burden and Cost of Gastroenteritis in a Canadian Community. *Journal of Food Production, 69*(3), 651-659.

Mangen M-J, AH H, De Wit GA. (2004) *Campylobacteriosis and sequelae in The Netherlands* 250911004/2004. National Institute for Public Health and the Environment, The Netherlands (RIVM).

Martin, S., Penttinen, P., Hedin, G., Ljungström, M., Allenstram, G., Andersson, Y., and Giesecke, J. (2006). A case-cohort study to investigate concomitant waterborne outbreaks of *Campylobacter* and gastroenteritis in Söderhamn, Sweden, 2002-3. *Journal of Water and Health, 04*(4), 417-424.

McAnulty, J.M., G.L. Rubin, C.T. Carvan, E.J. Huntley, G.Grohman and R.Hunter (1993), 'An outbreak of Norwalk-like gastroenteritis associated with contaminated drinking water at a caravan park', *Australian Journal of Public Health,* 14:1, pp. 36-41.

McGrogan, A., Madle, G. C., Seaman, H. E., and Vries, C. S. (2008). The Epidemiology of Guillain-Barré Syndrome Worldwide. *Neuroepidemiology, 2009*(32), 150-163. Retrieved from http://www.karger.com/ned

Mentzing, L. O. (1981). Waterborne outbreaks of campylobacter enteritis in central Sweden. *The Lancet, 318(*8242), 352-354.

Ministry for the Environment. (2007). Proposed National Environmental Standard for Sources of Human Drinking Water. *ME 936*. Retrieved from http://www.mfe.govt.nz/publications/rma/nes-draft-sources-human-drinking-water/index.html

Ministry of Health. (2007). *Weighted Inlier Equivalent Separations*. Retrieved from http://www.health.govt.nz/nz-health-statistics/data-references/weighted-inlier-equivalent-separations

Ministry of Health. (2009). *Report on New Zealand Cost-of-Illness Studies on Long-Term Conditions*. Retrieved.

Moore, D., Melleny, B., Valji, Y., and Tooth, R. (2010). Cost Benefit Analysis of raising the quality of New Zealand networked drinking water. *LECG*. Wellington.

Morens, D. M., Zweighaft, R. M., Vernon, T. M., Gary, G. W., Eslien, J. J., Wood. B. T., et al. (1979). A waterborne outbreak of gastroenteritis with secondary person-to-person spread. *The Lancet, 313*(8123), 964-966.

Nachamkin, I., Allos, B. M., and Ho, T. (1998). *Campylobacter* Species and Guillain-Barré Syndrome. *Clinical Microbiology Reviews, 11*(3), 555-567.

Nationaal Kompas Volksgezondheid. (2011). Retrieved from http://www.nationaalkompas.nl/algemeen/menu-rechts/english/

Neringer, R., Andersson, Y., and Eitrem, R. (1987). A water-borne outbreak of giardiasis in Sweden. *Scandinavian Journal of Infectious Diseases, 19*(1), 85-90.

O'Reilly, C. E., Bowen, A. B., Perez, N. E., Sarisky, J. P., Shepherd, C. A., Miller, M, D., The Outbreak Working Group, et al. A Waterborne Outbreak of Gastroenteritis with Multiple Etiologies among Resort Island Visitors and Residents: Ohio, 2004. (2007). *CID, 44*. 506-512. Retrieved from http://cid.oxfordjournals.org

Outcome Management Services Limited. (2004). *Assistance options for Safer Drinking Water Systems*. Wellington: Ministry of Health

Perera, S. and B. Adlam (2007). *Acute Gastrointestinal Study: General Practice Study*: ESR.

Pithadia AB, Kakadia N. (March–April 2010). "Guillain-Barré syndrome (GBS)". *Pharmacol*

Rep **62** (2): 220–32.

Rautelin, H., Koota, K., von Essen, R., Johkola, M., Siitonen, A., and Kosunen, T. U. (1990). Waterborne *Campylobacter jejuni* epidemic in a Finnish hospital for rheumatic diseases. *Scandinavian Journal of Infectious Diseases, 22*(3), 321-326.

Rees, J. H., Soudain, S. E., Gregson, N. A., and Hughes, R. A. C. (1995). *Campylobacter jejuni* Infection and Guillain-Barré Syndrome. *The New England Journal of Medicine*, *333*(21), 1374-1379.

Rice, G., Heberling, M. T., Rothermich, M., Wright, J. M., Murphy, P. A., Craun, F., and Craun, G. F. (2006). *Journal of Water and Health, 04*(2), 187-199.

Robak, A., and Bjornlund, H. (2009, September 2009). *Costs and benefits of compliance: New Zealand drinking water standards.* Paper presented at the Water 2020, Rotorua.

Rosevear, M. (2004). *Drinking Water Cost/Benefit Study: Final Cost/Benefit Report.*

Sacks, J.J., Lieb, S., Baldy, L. M., Berta, S., Patton, C. M., White, M. C., et al. (1986). Epidemic campylobacteriosis associated with a community water supply. *Am J Public Health, 76*(4), 424-428. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1646504

Sargeant, J. M., Majowicz, S. E., and Snelgrove, J. (2008). The burden of acute gastrointestinal illness in Ontario, Canada, 2005-2006. *Epidemiology and Infection, 136*, 451-460.

Scallan, E., Majowicz, S., Hall, G., Banerjee, A., Bowman, C., Jones, T., et al. (2005). Prevalence of diarrhoea in the community in Australia, Canada, Ireland, and the United States. *International Journal of Epidemiology, 34*(2), 16.

Schnabel, B. (2009) *Drastic consequences of diarrhoeal disease*, available at .http://www.dandc.eu/en/article/drastic-consequences-diarrhoeal-disease

Scott, G. W., Scott, H. M., Lake, R., and Baker, M. (2000). Economic cost to New Zealand of food-borne infectious disease. *New Zealand Medical Journal* (14 July 2000).

Sejvar, J. J., Baughman, A. L., Wise, M., and Morgan, O. W. (2011). Population Incidence of Guillain-Barré Syndrome: A Systematic Review and Meta-Analysis. *Neuroepidemiology, 2011*(36), 123-133. Retrieved from http://www.karger.com/ned

Simmons, G., Whittaker, Robyn, Boyle, Kerry, Morris, Arthur J., Upton, Arlo, and Calder, Lester. (2002). Could Laboratory-based notification improve the control of food-borne illness in New Zealand? *New Zealand Medical Journal, 115*, 237-240.

Statistics New Zealand. (2012). *New Zealand in profile: 2012*. Retrieved from http://www.stats.govt.nz/browse_for_stats/snapshots-of-nz/nz-in-profile-2012/earnings-from-wages-and-salaries.aspx

Statistics New Zealand. (2001). *Measuring unpaid work in New Zealand.* Wellington: Statistics NZ.

Ternhag, A., Torner, A., Ake, S., Ekdahl, K., and Giesecke, J. (2008). Short- and Long-term

Effects of Bacterial Gastrointestinal Infections. *Emerging Infectious Diseases, 14*(1), 143-148.

The Institute of Environmental Science and Research Ltd. Notifiable and Other Diseases in New Zealand: Annual Report 2012 Porirua, New Zealand. Retrevied from http://www.surv.esr.cri.nz/PDF_surveillance/AnnualRpt/AnnualSurv/2012/2012AnnualSurvRpt.pdf

Wheeler JG, Sethi D, Cowden JM, et al. Study of infectious intestinal disease in England: rates in the community, presenting to general practice, and reported to national surveillance. The Infectious Intestinal Disease Study Executive. *BMJ*. 1999;318:1046–50.

Vogt, R. L., Sours, H. E., Barrett, T., Feldman, R. A., Dickinson, R. J., and Witherell, L. Campylobacter enteritis associated with contaminated water. (1982). *Annals of Internal Medicine, 96*(3), 292-6. Retrieved from http://www.ncbi.nlm.nih.gov/pubed/7059090

World Health Organisation. (2013). *Burden of Disease and cost-effectiveness estimates*. Retrieved from http://www.who.int/water_sanitation_health/diseases/burden/en/index.html

Appendix 2 Data sources

Table 8 Data sources

Data source	Period start	Period end
Probably cases onset	t-30	t+12
Confirmed cases onset	t-1	t+8
Public hospital discharges	t-73	t+79
Sequelae public hospital discharges follow-up	t-43	t+140
Outpatient attendances	t-73	t+79
Emergency department attendances	t-73	t+79
GP consultations	t-73	t+79
Community Laboratory tests	t-73	t+79
Community Pharmaceutical dispensing	t-73	t+79
OTC pharmacy sales	t-43	t+48
Preschool absences	t-14	t+17
High school absences	t-49	t+47
Interview with GP manager	t+224	
Interviews with rest home managers	t+224	

Appendix 3 Analysing sequelae: Guillain-Barré syndrome

Guillain-Barré syndrome (GBS) is an autoimmune disease that is caused by a mis-targeted response of the immune system to foreign antigens such as infections. Various infections can cause this response, although campylobacter is the most common antecedent infection for GBS (Kuwabara 2010). In most cases, the original infection causing GBS is not determined. The determination of whether or not this case of GBS can be attributed to the campylobacter outbreak will have to be done epidemiological.

For an average population the annual incidence of GBS is about 0.6–4 occurrences per 100,000 people. Men are one and a half times more likely to be affected than women are. The incidence increases with age; there are approximately 1 cases per 100,000 people aged below 30 years and about 4 cases per 100,000 in those older than 75 years (Pithadia and Kakadia 2010).

Based on 2004-2007 hospital discharge data in New Zealand, it was estimated that 0.023 per cent of all campylobacter cases result in GBS, or 23 occurrences per 100,000 campylobacter infections (LECG 2010) The same number was found in Swedish data (Ternhag et al. 2008). No age or gender specific numbers were found for the occurrence of GBS syndrome in campylobacter infected populations.

To determine whether this specific case of GBS is most likely to be caused by a campylobacter infection, or by another cause, we compare the probabilities that this case (based on the gender and age of the individual) belongs to the group of people in the area that was infected with campylobacter or to the group that was not infected. To do so, we narrow our focus on the specific probabilities of the people in these two groups to contract GBS. Through backwards induction we look at the probabilities that the person with the disease belongs to either of these groups, given the fact that there was one case of GBS.

The following table shows the actual and estimated sizes of the population narrowed down to gender and age specific qualifications. However, to protect the anonymity of the patient involved, we cannot disclose the specific age and gender of the patient in this report. We use the data available and narrow down our probabilities, starting at the total population, and increasingly narrowing down on gender and on a smaller cohort of age groups in which the GBS patient falls.[22]

[22] For example, if our patient were to be 53 years old, the 10-year-wide cohort would be the population with an age between 50 and 59.

Table 9 Sizes of campylobacter and non-campylobacter population in the Town's area

	All population in the area	Campylobacter infected population in the area[23]	Non campylobacter infected population in the area
Total population	5,000-6,000	413	4,000-5,000
Individuals that fall in the same 30-year-wide age cohort as the GBS case	2,011	201	2,449
Total population with same gender as the GBS case	2,650	215	1,796
Individuals of the same gender as the GBS case, that also fall in the same 30-year-wide age cohort	987	99	888
Individuals that fall in the same 15-year-wide age cohort as the GBS case	1,057	153	904
Individuals that fall in the same 10-year-wide age cohort as the GBS case	670	93	577
Individuals of the same gender as the GBS case, that also fall in the same 10-year-wide age cohort	319	42	277
Individuals with the specific age and gender of the GBS case	31	6	25

We found through Bayesian inference, that it is more likely than not that the individual that developed GBS belonged to the group that was infected with campylobacter. The chances that this case, the only case of GBS in the 5 month period starting from the month of the outbreak, belonged to that group is at least 67.5 per cent.[24] This number seems rather low for any strong conclusions, but it increases when the age and gender specifics are taken into account, up to 96.8 per cent when taking only the population into account, with the exact

23 These numbers are estimated based on the assumption that the distribution of age and gender is similar in the group of identified cases as in the group of unidentified cases.

24 Which means that for every 3 cases of GBS found within this population 2 are expected to be within the *campylobacter* group *campylobacter* outbreak.

same age and gender as the GBS case.[25] The percentages belonging to the relevant population groups are given in the fifth column in Table 10.

These estimates are based on rather conservative assumptions. One of our referees suggested to use a lower incidence number of 1.6 per 100,000 population per year (based on McGrogan et al. 2009[26]) and to narrow our time period from 5 months to 2 months, as most GBS cases caused by campylobacter happen around 4 weeks after the initial infection. He also suggested comparing the total population with the campylobacter-infected population (as opposed to the non-infected with the infected population), to take into account the chances of someone with *campylobacter* and another infection coincidentally contracting GBS through the other infection. The last column in the table provides the probabilities with these less conservative assumptions. As can be seen in the table the probabilities get closer to our more conservative probabilities as the demographics of the case get narrowed down on age and gender.

We have decided to present our conservative estimates to rather err on the side of caution. However, Table 10 also provides the estimates based on the suggested changes to our assumptions made by the referee.

---

25 Which means that of every 31 cases of GBS found in individuals with the same gender and age as our GBS case in this group, 30 are expected to be due to campylobacter.

26 A. McGrogan et al. (2008) 'The epidemiology of Guillain-Barré syndrome worldwide', *The Lancet* 318(8242), 352-354.

Table 10 Probability of GBS case conditional on campylobacter infections

Population group age and gender	Expected # of GBS cases per 100,000 for average population per 5 months[27]	Expected # GBS cases in non-campylobacter-infected population in the area in the 5 month period	Expected # cases of GBS in campylobacter infected population[28]	Probability of a GBS case in this 5 month period coming from the campy group	Probability of a GBS case in the 2 month period following the outbreak due to campylobacter
Total population	0.96	0.0458	0.0950	67.5%	87.3%
Total population with same gender as the GBS case	0.77	0.0188	0.0461	71.1%	89.1%
Individuals that fall in the same 30-year-wide age-cohort as the GBS case	0.42	0.0075	0.0496	86.9%	93.7%
Individuals of the same gender as the GBS case, that also fall in the same 30-year-wide age cohort	0.33	0.0030	0.0227	88.5%	94.5%

27 Based on A. B. Pithadia and N. Kakadia (2010) 'Guillain-Barré syndrome (GBS)', *Pharmacol Rep* 62(2): 220-32.

28 These numbers are based on the ratio of 23 per 100,000 campylobacter infections, as found in LECG 2010 and A. Ternhag et al. (2008) Short- and long-term effects of bacterial gastrointestinal infections', *Emerging Infectious Diseases* 14(1): 143-48.

Population group age and gender	Expected # of GBS cases per 100,000 for average population per 5 months[27]	Expected # GBS cases in non-campylobacter-infected population in the area in the 5 month period	Expected # cases of GBS in campylobacter infected population[28]	Probability of a GBS case in this 5 month period coming from the campy group	Probability of a GBS case in the 2 month period following the outbreak due to campylobacter
Individuals that fall in the same 15-year-wide age cohort as the GBS case	0.25	0.0023	0.0351	93.9%	97.1%
Individuals that fall in the same 10-year-wide age cohort as the GBS case	0.39	0.0023	0.0213	90.4%	95.3%
Individuals of the same gender as the GBS case, that also fall in the same 10-year-wide age cohort	0.19	0.0005	0.0096	94.9%	97.6%
Individuals with the specific age and gender of the GBS case	0.18	0.0000	0.0014	96.8%	98.4%

Although it is impossible to show causality through this inductive Bayesian reasoning, the percentages are high enough to convince us that the costs of this case can be assigned to the *campylobacter* outbreak.