

CONSOLIDATED HEARINGS BOARD

IN THE MATTER OF Sections 2 and 3 and 6 (3) of the Consolidated Hearings Act, 1981, S.O. 1981, c.20;

— and —

IN THE MATTER OF Section 12(2) of the Environmental Assessment Act, R.S.O. 1980, c.140;

— and —

IN THE MATTER OF Sections 30, 35 and 38 of the Environmental Protection Act, R.S.O. 1980, c.141, as amended;

— and —

IN THE MATTER OF Sections 24 and 61 (2) of the Ontario Water Resources Act, R.S.O. 1980, c.361, as amended;

— and —

IN THE MATTER OF Section 28 (3) of, and Regulation 164 under, the Conservation Authorities Act, R.S.O. 1980, c.85, as amended;

— and —

IN THE MATTER OF Section 40(12) of the Planning Act, S.O. 1983, c.1, as amended; in connection with site plan control of the sanitary landfill site;

— and —

IN THE MATTER OF Section 22(1) of the Planning Act, 1983 in connection with a referral to this Board by the Honourable Bernard Grandmaitre, Minister of Municipal Affairs, on a request by the Regional Municipality of Halton to amend the Official Plan for the Town of Milton to redesignate a parcel of land comprising Part Lots 3 and 4, Concession 2 N.S. in the Town of Milton from "Agriculture" and "Conservation and Hazard Lands" to permit the construction, operation and maintenance of a landfill site, Minister's File No. 24-OP-0208-A01;

— and —

IN THE MATTER OF Section 34(11) of the Planning Act, 1983 in connection with an appeal to this Board by the Regional Municipality of Halton for an order directing an amendment to By-law 61-85 of the Town of Milton to rezone the lands situated at Lot 3 and part of Lot 4, Concession 2 N.S., in the Town of Milton from "Agriculture" to permit a regional sanitary landfill site and ancillary uses;

— and —

IN THE MATTER OF Section 15(1) of the Planning Act, R.S.O. 1980 ch.379 in connection with a referral by the Honourable Claude F. Bennett, Minister of Housing on a request by Tremaine Britannia Citizen's Group for consideration of part of the Official Plan for the Halton Planning Area with respect to Sections 1 to 5 inclusive, 7, 9 and 10 of Part III D3 Solid Waste Management, Minister's File No. OPC-0026;

— and —

IN THE MATTER OF Section 64 of the Ontario Municipal Board Act, R.S.O. 1980, c.347 as amended in connection with an application by the Regional Municipality of Halton for an order approving:

a) the acquisition of land for the construction, operation and maintenance of a sanitary landfill site to contain 7.96 million cubic metres of waste in the Regional Municipality of Halton and to do so by one of two alternative methods as follows:

- (i) landfilling at the site referred to in Halton's Environmental Assessment as Site F in the City of Burlington;
- (ii) landfilling at the site commonly referred to in Halton's Environmental Assessment as Site D in the Town of Milton

at an estimated cost of \$12,775,000.00, and the borrowing of money by way of temporary advances not exceeding in the aggregate such estimated cost pending the sale of debentures, and

(b) the issuance of necessary debentures to a maximum of \$12,775,000.00 for a term not to exceed fifteen years;

— and —

IN THE MATTER OF Section 193(5) and Paragraph 84 of Section 210 of the Municipal Act, R.S.O. 1980, c.302, as amended;

— and —

IN THE MATTER OF Sections 6, 7 and 8 of the Expropriations Act, R.S.O. 1980, c.148;

— and —

IN THE MATTER OF an undertaking of the Regional Municipality of Halton to provide facilities for the purpose of receiving, dumping and disposing of waste as required by section 137 of the REGIONAL MUNICIPALITY OF HALTON ACT, R.S.O. 1980, c.436, as amended, by acquiring the land for, constructing, operating and maintaining a landfill to contain 7.96 million cubic metres of waste in the Regional Municipality of Halton.

VOLUME: 105

HELD AT: Oakville, Ontario

DATE: March 14, 1988

OFFICIAL REPORTERS
NETHERCUT & COMPANY LTD.

185 RICHMOND ST. W.,
 TORONTO, ONT. M5V 1V3

TEL: 593-4802



Nethercut & Co. Ltd.

Toronto, Ontario

I N D E X

WITNESSES:

1	ANTHONY J. CRUTCHER	(Sworn)	
2	JOHN M. PETRIE	(Sworn)	
3	Examination in chief by Mr. McQuaid		25155

E X H I B I T S

7	<u>No.</u>	<u>Description</u>	<u>Page No.</u>
8	B-615	Witness statement and CV's dated March 1, 1988	25154
9	B-616	CV of Conestoga-Rovers	25154
10	B-617	Hydrogeologic Report Site F	25155
11	B-618	Hydrogeologic Report Site D	25155
12	B-619	Chart-area and volume of Bayview, Burlington & Site F	25206
13	B-620	Superimposed water level data	25281
14	B-621	Copy of Figure B.3.4 with groundwater flow direction	25288

16

17

18

19

20

21

22

23

24

25



THE CONSOLIDATED HEARINGS BOARD

1 IN THE MATTER OF Sections 2 and 3 and 6(3) of the
2 Consolidated Hearings Act, 1981, S.O. 1981, c. 20;

- and -

3 IN THE MATTER OF Sections 12(2) of the Environmental
4 Assessment Act, R.S.O. 1980, c.140;

- and -

5 IN THE MATTER OF Sections 30, 35 and 38 of the
6 Environmental Protection Act, R.S.O. 1980, c.141, as
7 amended;

- and -

8 IN THE MATTER OF Sections 24 and 61(2) of the Ontario
9 Water Resources Act, R.S.O. 1980, c.361, as amended;

- and -

10 IN THE MATTER OF Section 28(3) of, and Regulation 164
11 under, the Conservation Authorities Act, R.S.O. 1980,
12 c.85, as amended;

- and -

13 IN THE MATTER OF Section 40(12) of the Planning Act,
14 S.O. 1983, c.1, as amended; in connection with site
15 plan control of the sanitary landfill site;

- and -

16 IN THE MATTER OF Section 22(1) of the Planning Act,
17 1983 in connection with a referral to this Board by the
18 Honourable Bernard Grandmaitre, Minister of Municipal
19 Affairs, on a request by the Regional Municipality of
20 Halton to amend the Official Plan for the Town of
21 Milton to redesignate a parcel of land comprising Part
22 Lots 3 and 4, Concession 2 N.S. in the Town of Milton
23 from "Agriculture" and "Conservation and Hazard Lands"
24 to permit the construction, operation and maintenance
25 of a landfill site, Minister's File No. 24-OP-0208-A01;

- and -

17 IN THE MATTER OF Section 34(11) of the Planning Act,
18 1983 in connection with an appeal to this Board by the
19 Regional Municipality of Halton for an order directing
20 an amendment to By-law 61-85 of the Town of Milton to
21 rezone the lands situated at Lot 3 and part of Lot 4,
22 Concession 2 N.S., in the Town of Milton from
23 "Agriculture" to permit a regional sanitary landfill
24 site and ancillary uses;

- and -

22 IN THE MATTER OF Section 15(1) of the Planning Act,
23 R.S.O. 1980 ch.379 in connection with a referral by the
24 Honourable Claude F. Bennett, Minister of Housing on a
25 request by Tremaine Britannia Citizen's Group for
consideration of part of the Official Plan for the
Halton planning Area with respect to Sections 1 to 5
inclusive, 7, 9 and 10 of Part III D3 Solid Waste
Management, Minister's File No. OPC-0026;



- and -

IN THE MATTER OF Section 64 of the Ontario Municipal Board Act, R.S.O. 1980, c.347, as amended in connection with an application by the Regional Municipality of Halton for an order approving:

(a) The acquisition of land for the construction, operation and maintenance of a sanitary landfill site to contain 7.96 million cubic metres of waste in the Regional Municipality of Halton and to do so by one of two alternative methods as follows:

(i) landfilling at the site referred to in Halton's Environmental Assessment as Site F in the City of Burlington;

(ii) landfilling at the site commonly referred to in Halton's Environmental Assessment as Site D in the Town of Milton.

at an estimated cost of \$12,775,000.00 and the borrowing of money by way of temporary advances not exceeding in the aggregate such estimated cost pending the sale of debentures, and

(b) the issuance of necessary debentures to a maximum of \$12,775,000.00 for a term not to exceed fifteen years;

- and -

IN THE MATTER OF Section 193(5) and Paragraph 84 of Section 210 of the Municipal Act, R.S.O. 1980, c.302, as amended;

- and -

IN THE MATTER OF Sections 6, 7 and 8 of the Expropriations Act, R.S.O. 1980, c.148;

- and -

IN THE MATTER OF an undertaking of the Regional Municipality of Halton to provide facilities for the purpose of receiving, dumping and disposing of waste as required by section 137 of the REGIONAL MUNICIPALITY OF HALTON ACT, R.S.O. 1980, c.436, as amended, by acquiring the land for, constructing, operating and maintaining a landfill to contain 7.96 million cubic metres of waste in the Regional Municipality of Halton.

BEFORE: H. H. Lancaster, Q.C. - Chairman

Dr. D.J. Kingham - Member



Hearing conducted at The Oakville
Granary Commercial Centre, 105 Robinson
Street, Oakville, Ontario, on
Monday, March 14, 1988

VOLUME 105

APPEARANCES:

T.R. Lederer and H.D. Hodgson	for the Regional Municipality of Halton (Proponent)
J.R. Tidball	for the Ministry of the Environment
T. Vigod J.F. Castrilli	for the West Burlington Citizens Group
D. Estrin, F.E. Leitch and H. Dahme	for the Corporation of the Town of Milton
S.R. Garrod and A. Nurvo	for the Milton Area Citizens Coalition and several affected Milton area landowners
R.B. Tuer, Q.C. E.A. Cronk and F. Perrier	for National Sewer Pipe Limited
L.F. Longo	for Azova Investments Limited
M.J. McQuaid, Q.C. and C.J. Tzekas	for the City of Burlington
C. Mansfield	for the Ministry of Natural Resources
P. Renaud	for Cumis Limited



Nethercut & Co. Ltd.

Toronto, Ontario

APPEARANCES (Cont'd):

1		
2	C. Stevenson	for Framgard Holdings,
3	P. Hancock	Fosseri Investments
4		Limited, Seriphos
5		Investments Limited and
6		Topic Investments
7		
8	J.H. Olah	for the Halton Region
9		Conservation Authority
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		

* * * * *

Nethercut & Co. Ltd.
Official Reporters
185 Richmond St. W.
Toronto, Ontario
M5V 1V3

Per: C. F. Nethercut, C.V.R.



Oakville, Ont.
March 14, 1988

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

--- Upon Commencing at 9:30:

MR. LANCASTER: Please be seated. I see some familiar faces back.

MR. McQUAID: Yes, Mr. Chairman. New blood. We seem to be alternating every few weeks. I am going to begin, Mr. Chairman and Dr. Kingham by calling both Mr. Crutcher and Mr. Petrie and beginning with the hydrogeologic reports, if I could file a series of exhibits with the Board.

You will find the curricula vitae of both Mr. Crutcher and Mr. Petrie at the back of the witness statement dated March 1st, 1988, which I would ask you to mark.

MR. LANCASTER: That will be B-615, the witness statement and CVs.

---EXHIBIT NO. B-615: Witness statement and CVs dated March 1, 1988

MR. McQUAID: I will also be referring to a document which has the professional qualifications of the firm, Conestoga-Rovers & Associates, or CRA as it is referred to, and I would tender that. It is a type of curriculum vitae for the firm.

MR. LANCASTER: B-616.

---EXHIBIT NO. B-616: CV of Conestoga-Rovers

MR. McQUAID: There are two reports, one



1 on each of the sites, the first being an Evaluation of
2 Halton Regional Landfill Technical Study, Site F,
3 Hydrogeologic Report.

4 MR. LANCASTER: That is B-617.

5 ---EXHIBIT NO. B-617: Hydrogeologic Report, Site F

6 MR. McQUAID: The second has the same
7 title dealing with Site D.

8 MR. LANCASTER: B-618.

9 ---EXHIBIT NO. B-618: Hydrogeologic Report, Site D

10 DR. KINGHAM: We must get all the
11 paperwork done first this morning.

12 MR. LANCASTER: Is there anything
13 missing after the floor cleaning on the weekend?

14 MR. McQUAID: Mr. Crutcher, I would like
15 to start with you and I would like you to take Exhibit
16 615, the witness statement...

17 DR. KINGHAM: I wonder if the witnesses
18 should be sworn first?

19 ANTHONY J. CRUTCHER (Sworn):

20 DR. KINGHAM: And Mr. Petrie?

21 JOHN M. PETRIE (Sworn):

22 EXAMINATION IN CHIEF BY MR. McQUAID:

23 Q. Mr. Crutcher, immediately behind
24 the original typewritten pages in B-615, the four pages
25 of typewriting, we begin your curriculum vitae. I am



just going to ask you if you would, these were not
numbered and I would ask they be numbered in order from
1 through to -- and I haven't done the last few -- but
I think it is in the low teens.

DR. KINGHAM: You want to start with the
page labelled "Anthony J. Crutcher" as page 1?

MR. McQUAID: As page 1.

MR. CRUTCHER: I believe it goes to 15.

MR. LANCASTER: What Ms. Cronk refers to
as pagination.

MR. McQUAID: Right.

Q. Mr. Crutcher, I would first like
to start with your schooling and employment record
portion. We note you obtained a Bachelor of Applied
Science in 1976, but going down in the employment
portion starting in 1973, could you indicate to us,
particularly with reference to the program they have at
the University of Waterloo where you work and go to
school, just what schooling you followed during that
period and what work you were doing as part of your
schooling as well?

MR. CRUTCHER: A. I went to the
University of Waterloo and took civil engineering and I
commenced in 1971 and graduated with a Bachelors, a
Bachelor of Applied Science in 1976 and subsequently a



1 Master of Applied Science in Civil Engineering in 1977.
2 Because of the nature of the University, they have a
3 co-operative program which would entail going out on
4 work terms and going to school on an alternate basis
5 and you would work four months on and four months off
6 and you would have an opportunity to get some
7 experience while proceeding through school, and that is
8 particularly advantageous because it allows you to
9 direct what form you want to take as you are proceeding
10 through university.

11 Q. So your actual academic experience
12 begins in 1971?

13 A. That is correct.

14 Q. Then you are going through the
15 first couple of years and then we see beginning in 1973
16 you began to undertake work, and is this on the work
17 terms you were referring to?

18 A. Correct. In 1973 I worked two
19 work terms, total of eight months with Environment
20 Canada in Ottawa dealing with environmental matters.
21 Subsequently the next three work terms, which are
22 evident through the research assistant which is two
23 work terms and then the June engineering work terms
24 with Frank A. Rovers & Associates as my last work term
25 dealing again with environmental matters.



1 The University work dealt primarily with
2 analyzing landfill leachates, doing column studies on
3 the attenuation characteristics of area soils exposed
4 to leachate and then the work with Frank A. Rovers &
5 Associates was dealing with full applications of that
6 work and monitoring various landfill sites.

7 Q. The research assistant component
8 you referred to was the University work involving
9 leachate studies and column studies. Is that right?

10 A. That is correct.

11 Q. What do you mean by column
12 studies?

13 A. The purpose of the research was to
14 attempt to ascertain the attenuation characteristics of
15 various overburden soils and a column was packed with
16 soils, sands, silts and clays and leachate was exposed
17 or ponded on these soils and we measured the absorptive
18 capacity of the soils.

19 My responsibility was more as a
20 technician since I had not graduated at that time and I
21 was responsible for the maintenance of the columns, the
22 sampling and doing the analysis.

23 Q. Coming into 1975-1976, it is noted
24 there that you were a junior engineer with Frank A.
25 Rovers & Associates, and I wonder if you could explain



1 for the Board Mr. Rovers' association with your current
2 company?

3 A. Mr. Rovers is the Rovers of
4 Conestoga-Rovers. My association with Frank Rovers
5 commenced in 1974. The research assistant I was
6 working under was Dr. Graham Farquhar and he had a
7 doctoral student who was Frank Rovers, and the work I
8 was doing was for Frank Rovers and the research
9 assistance, and that carried on, and subsequently I was
10 retained directly by Frank's company, which is Frank A.
11 Rovers & Associates, at that time to do work in the
12 field.

13 Q. When you were a junior engineer,
14 have you now obtained your Bachelor of Applied Science
15 in 1976 or is the term before that?

16 A. Over that period in '75 and '76
17 when I was on my last work term and I was working part-
18 time with Frank Rovers, and then I continued working
19 part-time throughout my Masters program for Frank
20 Rovers and subsequently with Conestoga-Rovers when that
21 firm was formed.

22 Q. Could you give us your Masters
23 program which begins where on this chronological order?

24 A. I graduated in May of 1976 and
25 commenced immediately on my Masters program and looking



1 through employment, '76 to '77, teaching assistant, was
2 a teaching assistant for various courses at the
3 University of Waterloo. I also worked as I indicated
4 on a part-time basis with Conestoga-Rovers &
5 Associates.

6 Q. That is where we see the entry
7 project engineer, 1976 to 1979?

8 A. Yes.

9 Q. You graduated in May of 1976 with
10 your B.Sc. in Civil Engineering and can you indicate to
11 the Board was there anything particular in your
12 schooling that you were concentrating on that is of
13 relevance to the evidence you will be giving the Board?

14 A. When I went to University I was
15 not particularly well directed in what area I wanted to
16 proceed and through my work terms I became quite
17 interested in environmental matters initially with
18 Environment Canada and subsequent from that time I
19 oriented all of my activities at University where I had
20 electives and work terms into environmental areas and
21 have subsequently proceeded with that for my complete
22 professional career.

23 Q. Coming into your Masters period,
24 could you just give us the history. Are we talking
25 about a two-year program, 1976 and '77?



1 A. Not a defined program, but a
2 defined amount of work to be undertaken. I had been
3 working at the University for two to three terms and I
4 was very familiar with the program and I managed to
5 undertake my Masters in a shorter than normal period,
6 just over a year. I undertook the Masters on a
7 computer modeling of leachates from a landfill.

8 Q. You completed that then in 1977?

9 A. That is correct.

10 Q. And obtained your Masters?

11 A. Yes. I finished at the University
12 in I believe May of 1977 and actually received my
13 degree, I believe it was in the fall convocation.

14 Q. Turning over to what we have
15 numbered as page 3, there are a series of publications,
16 published refereed papers, and I wanted you to add to
17 that list as you indicated to me over the weekend, you
18 have not included the specific detailed title of your
19 thesis?

20 A. Correct.

21 Q. Would you give that to us and
22 where does it go in terms of the numbering?

23 A. I would put it right after No. 1,
24 so perhaps it could be labelled 1A, and it is entitled,
25 "Computer Model Analysis".



1 Q. Go slowly. Computer ...

2 A. Computer Model Analysis of
3 Contaminant Migration from Sanitary Landfills, by
4 Anthony James Crutcher, University of Waterloo
5 copyright dated 1977.

6 Q. Continuing back at page 1 of this
7 portion of the exhibit, it is noted the that you joined
8 Conestoga-Rovers & Associates as a project engineer in
9 the period 1976 to 1979?

10 A. Yes. As I indicated, I was on a
11 part-time basis while I was undertaking my Masters
12 program. My Masters program was in fact done in
13 conjunction with the firm and the funding for
14 undertaking the model analysis was from Environment
15 Canada to Conestoga-Rovers and subsequently from
16 Conestoga-Rovers to the University at which I undertook
17 my Masters.

18 As you can see, I was integrated with
19 Frank Rovers and Conestoga-Rovers essentially since
20 1974.

21 Q. I was going to ask you to turn to
22 the second exhibit we filed this morning, 616, the
23 document describing the qualifications of Conestoga-
24 Rovers & Associates, and I wonder by reference to this
25 if you could explain to the Board what the work of



1 Conestoga-Rovers is and its approximate size, divisions
2 and so on?

3 A. The firm Conestoga-Rovers is an
4 amalgamation of two firms, one being Conestoga
5 Engineering and the other Frank A. Rovers & Associates.
6 That amalgamation happened in 1976. The work that the
7 firm principally undertakes is in environmental
8 engineering, hydrogeology and municipal engineering.

9 At the present time we employ
10 approximately 170 people and we have three offices, the
11 head office in Waterloo, Ontario, branch offices in
12 Niagara Falls, New York, and St. Paul, Minnesota. The
13 firm is divided into four principal sections and if you
14 could refer to page 2 of the document, Exhibit B-616,
15 those divisions are indicated.

16 Firstly, there is the environmental
17 services division, the largest of the company, and that
18 division looks after doing preliminary site
19 evaluations, environmental impact assessments,
20 conceptual designs and monitoring. I am a co-manager
21 of that section in conjunction with Frank Rovers and my
22 present responsibilities in that is essentially looking
23 after the Canadian environmental engineering matters
24 that the firm undertakes.

25 The second division is a construction



1 services section where the work undertaken by the
2 environmental services is carried on into a detailed
3 design, construction phase, and then actual doing the
4 field administration of that construction.

5 We have a technical support services
6 section which is in fact what supplies specialized
7 expertise to each group within the company and that
8 deals, or the largest section of that is our
9 hydrogeology group of which John Petrie is a member and
10 I manage the hydrogeology group as well as my
11 responsibilities with the environmental services
12 section.

13 We also have an analytical section for
14 risk assessment and other related expertise.

15 The fourth section is our municipal
16 services. As I indicated initially, the firm undertook
17 a considerable amount of municipal engineering and that
18 has now been well overtaken by environment and the
19 municipal services provides support to the
20 environmental section and also undertakes individual
21 projects doing municipal engineering themselves.

22 Q. Looking at B-616, there is
23 reference at page 3 to a list of the various components
24 of expertise that the company offers in terms of all
25 types of studies, implementation design, construction



1 and so on and we see that set out there, and then going
2 over to page 5 there are some references and
3 immediately behind page 7 there is a list of selected
4 projects that the company has been involved in and a
5 description of the type of work that has been
6 undertaken in those particular projects?

7 A. That is correct.

8 Q. As it is indicated it is a
9 selection and this is not every project you have been
10 involved in?

11 A. That is correct. It was intended
12 to provide a reflection of the kind of work the firm
13 did and we felt in providing the qualification package
14 that it was better to indicate the work we had done
15 rather than the work we can do.

16 Q. That is the firm, and so now I
17 would like to go back to B-615 and your specific
18 experience, particularly as it relates to the subject
19 problems or matters before the Board.

20 Could I take you now to that period, I
21 guess 1976 to 1979, you were originally a project
22 engineer with Conestoga-Rovers & Associates and you
23 were promoted to an associate, it is noted, in 1979 to
24 1982, and then in 1982 you became a principal?

25 A. That is correct.



1 Q. In dealing with B-616 you
2 commented on, I think, the role you carry on currently
3 and you indicated you were co-manager together with
4 Mr. Rovers of the environmental section?

5 A. Correct.

6 Q. Could you indicate to us
7 approximately how many employees, engineers, however
8 you want to break it down, you are reasonable for as
9 co-manager of the environmental services section?

10 A. I have the environmental services
11 and hydrogeology section as the two are quite
12 integrated together. In total I am responsible for in
13 the order of 20 to 30 people and a professional staff
14 or half of that would be professional staff and the
15 balance would be technicians to assist the technical
16 staff.

17 As I indicated, the firm is
18 approximately 170 employees and there are six partners
19 of the firm, and each partner takes their
20 responsibility in looking after the employees of the
21 firm.

22 Q. You indicated that in addition to
23 being co-manager of environmental services you are also
24 manager of the hydrogeology section which is under the
25 technical support component or section?



1 A. Yes. The reason I am managing
2 that section is because Conestoga-Rovers is a
3 consulting engineering firm and we do a considerable
4 amount of hydrogeology. However, we believe that the
5 hydrogeology has to have a means to the end, if you
6 want to go some place with it, and we feel that the
7 engineering is a very major component and so the two
8 are integrated together.

9 John Petrie, for example, is truly a
10 hydrogeologist with a geology background where I have
11 hydrogeology from an engineering background, and it is
12 felt it would be wise to have a manager of the group
13 being an engineer to integrate with the engineering
14 components of the firm.

15 Essentially my responsibilities from the
16 managing of the hydrogeology group is overseeing the
17 work that is undertaken and to ensure there is proper
18 integration of the hydrogeology with the engineering.

19 Q. In that group you are mentioning,
20 20 to 30 of whom are professional staff, does that
21 include the hydrogeologists under the technical support
22 section?

23 A. It does.

24 Q. How many hydrogeologists,
25 approximately, would there be in that group?



1 A. Four or five.

2 Q. Can I ask you, and we can pick up
3 continuing on page 1, the affiliations, professional
4 organizations you are affiliated with; a registered
5 civil engineer of Ontario and then the other
6 associations you have listed there, and then there is a
7 profile of professional activities. Are these
8 activities where you have been directly involved in
9 various components?

10 A. It is a listing of activities
11 which I feel I am qualified to undertake and obviously
12 it depends on what the application is, but this is what
13 I believe I am qualified to undertake.

14 Q. Then I am going to ask you to sort
15 of highlight some of the specific activities that
16 relate to the subject matter before the Board and so
17 let's continue over to page 2 which continues to list
18 the professional activities and then from pages 3
19 through 6 there is various published publications you
20 have been an author or co-author of. Is there any of
21 particular note you would indicate to the Board of
22 specific reference to the matters before the Board?

23 A. All the papers and various
24 publications are related to waste disposal in some
25 manner. Initially the refereed papers, for instance,



1 if you take item 1 on page 3, it dealt with a paper
2 generated essentially through my thesis work, my
3 Masters work at the University in conjunction with
4 Dr. John Sykes. One of my early projects with the
5 firm or CRA was dealing with capturing of landfill gas
6 and I became quite well noted across Canada and the
7 United States in that particular area and you will note
8 that much of my publication work and papers dealt with
9 landfill gas.

10 There is also a paper which has some
11 relevance referred to on page 3, paper 4. I jointly
12 authored a paper on leachate collection design for
13 containment landfills and that was documenting some
14 work we had undertaken at the Keele Valley landfill
15 site in Toronto on the design of the leachate
16 collection system at that site and that is more
17 pertinent to the operation and design component of this
18 hearing.

19 Q. I might indicate, Mr. Chairman and
20 Dr. Kingham, that I am proposing that Mr. Crutcher and
21 Mr. Petrie, following qualification and going through
22 their reports, that we would concentrate on the
23 hydrogeological aspects of the two sites and then it is
24 my proposal to recall, as it were, Mr. Crutcher, to
25 deal with certain design and operations aspects as well



1 and there are two separate reports we will be filing
2 later in the proceedings in that respect.

3 Mr. Crutcher ...

4 MR. ESTRIN: Mr. Chairman, Mr. McQuaid
5 did advise us through correspondence of that intention
6 and I have no particular quarrel with that. However, I
7 do have a concern and I am not sure where it takes us
8 in terms of time, but there are other documents, other
9 reports, the design and operation studies, other
10 documents most recently received in the last week or so
11 that relate to hydraulic conductivity studies at Site
12 D, for example. I guess I am concerned to know and I
13 will certainly discuss it with Mr. McQuaid at the
14 break, and then I will advise the Board if there are
15 any other further problems, but we just received the
16 witness statement and report related to hydraulic
17 conductivities undertaken at Site D and from the
18 correspondence it would appear that it is
19 Mr. McQuaid's intent to call those witnesses if they
20 are indeed called later.

21 I am not sure where later fits in terms
22 of hydrogeological evidence versus design and
23 operations reports and so I am having some concern
24 about the nature of all the evidence and where it fits
25 in because somewhere in the middle he is also going to



1 call witnesses dealing with waste capacity which takes
2 us into another whole series of reports. I will be
3 speaking to Mr. McQuaid at the break to see if we can
4 come to some understanding as to how this proceeds,
5 because I am a bit concerned having to cross-examine
6 twice on areas that will relate with each other.

7 MR. LANCASTER: Perhaps you can resolve
8 that matter with Mr. McQuaid.

9 DR. KINGHAM: It might be useful for us
10 to have a general sketch of the Burlington case as it
11 will develop as this is the first we understood and
12 Mr. Crutcher will be coming back to talk about the
13 design and Mr. Estrin has made us aware of some other
14 work on hydraulic conductivity and will that be part of
15 the hydrogeological work or is it not in the first
16 couple of weeks or will it come out later?

17 MR. MCQUAID: Just to deal with this
18 second question, you may recall there was a Golder
19 document indicating what the hydraulic conductivity of
20 the till was at Site D put to Dr. Rowe and
21 Dr. Charlesworth and some question was raised as to
22 that particular sample having regard to the time or age
23 of the core.

24 As a result of that criticism that had
25 been raised as to the age of the sample, we undertook



1 through CRA's direction another sample, a current
2 sample, and as soon as that information was available,
3 which was the beginning of last week, that report was
4 filed with all of the solicitors, all of the interested
5 parties.

6 At the same time we served the
7 curriculum vitae of Mr. Lahti who was one of the co-
8 authors or co-testers of the earlier report and of the
9 more recent one. In terms of timing I wanted my
10 friends to have this more recent report to be able to
11 discuss it with their technical people and so on.

12 It would be my anticipation, and I can
13 speak with Mr. Estrin at the break and with the other
14 counsel, but at the conclusion of the hydrogeology, if
15 necessary and if advised, I would call Mr. Lahti at
16 that point for any questions that would be put to him
17 about the tests and so on.

18 So, I guess I am saying in a sense, we
19 will concentrate on the hydrogeology and these tests at
20 the outset and then following cross-examination on
21 those aspects, hydrogeological aspects, it was my
22 proposal to introduce a panel that would deal with
23 waste quantities and some population figures and that
24 lays some foundation for some of the evidence of the
25 design and operation of the proposed sites.



1 So, there will be a panel of two
2 witnesses, Mr. Stamm and Mr. Mereu from the CRA firm
3 who has been involved in the waste quantity component
4 calculations and so on, and then it had been proposed
5 we would recall Mr. Crutcher with one or two municipal
6 engineers from the CRA firm and they would deal with
7 the design and operation component of the two sites.

8 That basically would be the first -- we
9 were anticipating about the first five or six weeks of
10 the evidence we would anticipate, and then there are a
11 series of other witnesses, other panels, sir, but we
12 are concentrating at the outset on the hydrogeology,
13 the design and operations.

14 DR. KINGHAM: We could understand the
15 complication of adhering to the 30-day rule if you just
16 had these tests done since the last evidence was
17 presented.

18 MR. McQUAID: I might add that you will
19 hear evidence as well that CRA have been charged by the
20 City of Burlington to report to the Minister of the
21 Environment on certain tests they have been performing
22 on the Bayview site. You have heard a lot about the
23 Gartner Lee Burlington tests and so on, and there are
24 also a series of reports which CRA have been required
25 to submit to the Minister of the Environment and it was



1 necessary to re-check certain samples that had been
2 taken within the last couple of weeks.

3 Again, a draft report was forwarded to
4 my friends because of the test results and CRA asked
5 Burlington to be allowed to doublecheck some of the
6 results and that report in terms of its final form we
7 are expecting would be filed with my friends probably
8 tomorrow. However, they have the draft report in the
9 early part of last week, so on the 30-day rule we were
10 under some pressure because of the re-testing, but
11 hopefully, with the time we have ahead of us in terms
12 of in-chief and cross-examination, I think that that
13 problem will work itself out but both in the testing of
14 hydraulic conductivity and these more recent tests at
15 Bayview, the best we can do as file them as early as
16 possible and hope that the time that we will be using
17 will allow my friends to examine them with their
18 experts.

19 I might add we apparently have received
20 another Gartner Lee report ourselves last Thursday or
21 Friday and again CRA will be trying to examine that and
22 fit that into the evidence so you will have as current
23 a picture as we can possibly give, and subject to some
24 finality at some point.

25 MR. CRUTCHER: And time.



1 DR. KINGHAM: I was wondering when
2 Mr. Hodgson was going to make that observation.

3 MR. HODGSON: The observation is by way
4 of explanation and not an apology. The Gartner Lee
5 report my friend Mr. McQuaid referred to, is Gartner
6 Lee's regularly scheduled annual monitoring report of
7 the Burlington landfill site required under the
8 Certificate of Approval for that site, and to be filed
9 with the Ministry of the Environment by March 31, of
10 each calendar year.

11 The report, or I became aware of the
12 fact the report was in preparation three weeks ago and
13 there was a lot of pressure put on Gartner Lee to get
14 it done and it is done, and I was able to get enough
15 preliminary copies to give to some of my friends on
16 Friday and I will have copies for everyone else
17 including the Board tomorrow, but I don't know how it
18 will get into evidence because I will not introduce it
19 into evidence, but it will be sitting here in the room.
20 And I am sure somebody will make sure that it crosses
21 your path.

22 MR. MCQUAID: I might add that there was
23 no criticism at all in my commenting on that, and as a
24 matter of fact I wrote to Mr. Lederer some few weeks
25 ago and said that I understood that that report was



1 scheduled in the ordinary course, please make the
2 details available to us as early as possible.

3 MR. LANCASTER: The only concern the
4 Board has is with the proposed timetable.

5 MR. McQUAID: I think we are all aware
6 of that concern, sir.

7 Q. All right, Mr. Crutcher. Now I am
8 going to go to page 7 as we have numbered the pages in
9 your curriculum vitae and there is a section of
10 references to sites running 1 through 39 on the 15th
11 page of your curriculum vitae, and it begins with the
12 heading "Ontario Landfill Experience."

13 MR. CRUTCHER: A. Correct.

14 Q. First of all, could I ask you to
15 explain for the Board, what have you listed here and
16 what was the purpose of listing it?

17 A. The listing I have provided here
18 is a listing or chronological listing of the work I had
19 undertaken dealing with municipal landfill sites in
20 Ontario. It was attached to my curriculum vitae at the
21 request of Mr. McQuaid so that he could get a feeling
22 for the sites I had been working on and it is not
23 normally a part of my curriculum vitae, and it is only
24 dealing with landfills.

25 I did note that -- landfills or



1 municipal waste -- but I did note in reviewing this
2 that I did include one which does not quite follow that
3 criteria and perhaps we could note that, if I can find
4 it. It is labelled as the Tricil landfill, No. 13.
5 That is a hazardous waste landfill and would not comply
6 under that criteria, and that was inadvertent. I have
7 not listed industrial landfills or hazardous waste
8 landfills or things of that sort, I was attempting to
9 list the sites which would have similar contaminants
10 that would be experienced at the proposed site.

11 Q. I indicated to the Board that back
12 at pages 1 and 2 you had listed a significant number of
13 various professional activities of investigation,
14 design and a research nature and they speak for
15 themselves. All those items back at 1 and 2 are
16 individual activities you have been involved in since
17 your graduation; is that correct?

18 A. That is correct. They have all
19 been associated with my profession after graduation.

20 Q. I thought I would ask you dealing
21 specifically with the Ontario landfill experience
22 portion at pages 7 through 15, if you would take some
23 of the more representative landfill sites that you have
24 been involved in that might bear a relation to the
25 subject applications before the Board, or subject



1 application?

2 A. To some extent all of the
3 landfills have some application, but I would refer to a
4 few of them just to give a feel for my experience and
5 how it would apply to this application before the
6 Board.

7 If you refer to item 7 on page 8, that
8 is the Stouffville landfill site, and this is a large
9 landfill site located near the Town of Whitchurch-
10 Stouffville and it is now closed but it was operated by
11 Waste Management of Canada Inc. I have been involved
12 in a very active professional sense since 1977, but
13 prior to that in working with Frank A. Rovers &
14 Associates I was also involved in doing some of the
15 groundwater monitoring at that site and some of the
16 actual analysis of the groundwater samples through my
17 work experience.

18 The Stouffville landfill site is and has
19 been a controversial landfill site and has gone through
20 a very extensive hydrogeologic investigation and two
21 hearings before the Environmental Assessment Board and
22 a hearing before the Environmental Appeal Board and it
23 ended with a negotiated settlement for the closure of
24 the site to the satisfaction of the Ministry of the
25 Environment, Waste Management of Canada, and the



1 residents in the area.

2 My responsibilities on that particular
3 site have varied. We are currently still working on
4 that site through the monitoring programs and my
5 responsibility initially was, as indicated, taking the
6 samples at the site as a student and doing some of the
7 design and support of the applications for the
8 expansion of the site, undertaking and then overseeing
9 the hydrogeologic investigations at the site and,
10 subsequently, the closure plans for the landfill site
11 and now I oversee all of the monitoring undertaken at
12 the site, and it has quite a comprehensive monitoring
13 program that is filed with the Ministry of the
14 Environment on a yearly basis.

15 Q. Could you indicate to the Board
16 what type of strata or soil is that Stouffville
17 landfill site in?

18 A. The Stouffville landfill site is
19 situated on the Oak Ridges Moraine and the principal
20 soil is a clay till with the lower portion of the site
21 getting into a bit more of silt till, and it also
22 overlies a major aquifer beneath the till landfill.

23 Q. Could you continue and are there
24 other sites?

25 A. The second site I would like to



1 identify is item 9 on the same page, page 8, the Keele
2 Valley landfill site. This is a very large landfill
3 site in Metro Toronto and located adjacent to the Town
4 of Maple, now the Town of Vaughan. It is the largest
5 landfill site in Canada and when completed it will
6 contained approximately 20 million tonnes of waste.

7 Our responsibilities or my particular
8 responsibilities have been dealing initially with Waste
9 Management of Canada who at that time were going to be
10 the operators and my responsibilities with Waste
11 Management were the design of the landfill site, the
12 leachate collection system and the bottom contours and
13 final contours, surface water drainage. I worked with
14 a team from our office and for all of that I was
15 responsible and the project manager for all of those
16 items.

17 After the design aspects of the site,
18 the site was sold to Metropolitan Toronto and we were
19 retained by Metropolitan Toronto to carry on providing
20 operating advice to Metro Toronto. Our primary
21 responsibilities dealing with landfill gas, the
22 collection and the monitoring, leachate recirculation
23 within this site, surface water drainage and recharge
24 and, because of our broad nature in dealing with waste
25 management, all aspects of waste management, we were



1 also retained to provide what I call general
2 engineering services and when an item comes up on the
3 site which needs some work done on and their internal
4 forces cannot do it, then we normally would undertake
5 that and that could range from municipal type
6 engineering services to more specialized work.

7 Q. Could you again give the Board
8 some kind of idea of what type of strata is involved in
9 the Keele Valley landfill site?

10 A. The Keele Valley landfill site is
11 situated in a mined-out sand and gravel pit and the
12 site has been highly engineered and it has a clay liner
13 put in place with a very extensive monitoring system.
14 We are not involved with a liner per se and we have a
15 lot of interaction with the consultants dealing with
16 that, that being Golder & Associates on the performance
17 of that clay liner.

18 Q. All right.

19 A. The third site I would like to
20 discuss is the Waterloo landfill site.

21 Q. What number is that?

22 A. No. 25 on page 12. We have been
23 involved in the Waterloo landfill site for a
24 considerable period of time. The firm was involved
25 initially with the approval process of that back in '72



1 and '73, but I personally was not involved until 1981
2 when we were commissioned to undertake a hydrogeologic
3 investigation of a potential expansion area to the site
4 and subsequently have been retained as a sub-consultant
5 to MacLaren Engineers to take that expansion and the
6 existing landfill site through an environmental
7 assessment under the Environmental Protection Act, that
8 documentation and subsequent hearing for the expansion
9 of the Waterloo landfill site.

10 The work I have been responsible for was
11 initially the hydrogeology of the expansion area and
12 then providing advice to the Region on the operations
13 of the landfill site and then, more recently, the
14 actual design of the complete landfill site and the
15 expansion area, a redesign of the existing site as we
16 were raising the site somewhat, the design of a
17 leachate collection system for the existing site,
18 overseeing the construction, and that is being done
19 through another division of ours so I have a lesser
20 responsibility on that, and, at the present time, we
21 are just finalizing our reports on the hydrogeology and
22 the design of that site to be submitted to the Ministry
23 of the Environment.

24 Q. All right.

25 DR. KINGHAM: What kind of geology is



1 that and where is that, sir?

2 MR. CRUTCHER: The Waterloo landfill
3 site is located within the City of Waterloo and a
4 portion of it is within the City of Kitchener. It is
5 on a clay till base with a very significant aquifer
6 approximately 130 feet below the till mantle.

7 MR. MCQUAID: Q. Are there any others
8 of particular note, Mr. Crutcher?

9 A. I have one other I would like to
10 highlight, No. 27, the Sarnia landfill site on page 12.
11 I have been involved with the City of Sarnia on the
12 Sarnia landfill site since 1981. At that time the city
13 site was experiencing considerable leachate problems
14 because it is situated in a very tight clay till or
15 lacustrine clay down in the Sarnia area, and the site
16 had not been engineered for leachate collection, and
17 essentially it had been excavated and placed with waste
18 and the leachate had built up in the site and was
19 discharging.

20 So, our responsibility was initially to
21 deal with the leachate situation which required a
22 redesign of the landfill site, mainly because it was
23 designed with a flat top and did not promote drainage
24 and going through an approval process through that
25 redesign, the designing of a leachate collection system



1 for the site, the overseeing of the construction of
2 that leachate collection system, and again my
3 responsibilities are somewhat diminished when we get
4 into the construction area and, most recently, we are
5 now undertaking a pilot scale leachate treatability
6 study on the site and that is underway right now, and
7 it is scheduled to have a full scale leachate treatment
8 plant at that site in the latter part of this year or
9 early next year.

10 I should note that leachate treatment is
11 a fairly new -- on-site leachate treatment is a fairly
12 new procedure and in fact this will be the first, as
13 far as we are aware, the first on-site leachate
14 treatment system being used in Ontario or Canada.

15 So, it will be quite a novel approach
16 and I was very excited to be involved in that.

17 Q. Let me take you back to, I guess,
18 the first page where you list your landfill experience,
19 back at page 7, and if you could very quickly go
20 through these sites, and could you indicate to the
21 Board what strata or what type of soils are these sites
22 located in, and perhaps I can ask you at the outset if
23 any of them are located in fractured rock or a
24 fractured shale setting of the type we have been
25 discussing at Site F?



1 A. None of the sites are located in a
2 fractured shale. One of the sites is located on top of
3 a fractured limestone, but our responsibilities have
4 not dealt essentially with that, an evaluation of that,
5 so it is not all that pertinent to my personal
6 experience. If I may just list them, these sites.

7 Site 1, the Mississauga landfill site is
8 situated on a silty sand. The Hanover landfill site,
9 No. 2, is again on a silty sand. No. 3 is the St.
10 Thomas landfill site which is in a clay till. 4, the
11 Aurora landfill site is in a silty sand. 5, East
12 Gwillimbury landfill site is in a silt. No. 6, the
13 West Gwillimbury landfill site is silt. No. 7, the
14 Stouffville landfill site is clayey till.

15 No. 8 is Kincardine landfill site which
16 is silt. No. 9, the Keele Valley landfill site is
17 situated in a sand and gravel pit with a clay liner.
18 No. 10 is the Kitchener landfill site and it is in a
19 till, a very mixed geology at the Kitchener site, but
20 essentially a till. No. 11, the Petrolia landfill
21 site, is in a clayey till. No. 12, the 20-acre Maple
22 landfill site is in a clayey till and that site is
23 adjacent to the Keele Valley landfill site but is
24 sitting on a till mantle whereas the Keele Valley
25 landfill site is situated at the bottom of a pit.



1 13, the Tricil landfill site is the site
2 I had indicated which dealt primarily with hazardous
3 waste but it is a clay till, a lacustrine clay. The
4 Lucan landfill site is a clay till. No. 15, the Tara
5 landfill site is a sandy silt. No. 16, St. Marys
6 landfill site is in a clay till. No. 17, the Essex
7 County landfill site is a clay, and that is Site No. 1.
8 No. 18 is the Essex County landfill site, No. 2, which
9 is in a sand. 19 is the Essex County landfill site No.
10 3, which is in clay.

11 No. 20 is the Adelaide landfill site
12 which is in a clay, or I should say a clay till. No.
13 21 is the Adjala landfill site and in fact we did not
14 proceed, but the work we were undertaking was in a silt
15 environment. No. 22 is the Brantford landfill site
16 which is in a sandy silt. No. 23 is the Seaforth
17 landfill site, and there are a variety of sites we are
18 dealing with and in fact it is looking for a new site,
19 but essentially the sites we were dealing with were in
20 a clay till.

21 No. 24 is the Chesley landfill site, and
22 we are dealing with a clay. 25 is the Waterloo
23 landfill site which is a clay till. No. 26 is the
24 Beare Road landfill site, a clay till. 27 is the
25 Sarnia landfill site which is a clay till and



1 lacustrine clay. 28 is the Southwold landfill site
2 which is a clay till. 29 is the Upper Ottawa Street
3 landfill which is the limestone bedrock site I
4 indicated, but our responsibilities or the
5 responsibilities I have do not deal with the
6 hydrogeology. 30 is the Old Welland Canal landfill site
7 and it is an excavated canal or it was a filled-in part
8 of the canal in Welland and it was based in clay.

9 31 is the Township of Hay which is a
10 landfill site in silt. 32 is the Onaping Falls
11 landfill site which is a site we were looking at but
12 which we did not proceed with on a sand. No. 33 is the
13 Burlington landfill site, the present landfill site,
14 and our involvement was with the last expansion of that
15 site and was on a clay till and obviously we have also
16 dealt with the shale component to some extent at the
17 front, but we are primarily referring to the expansion
18 area.

19 The North Bay landfill site is in a
20 sand. 35 is the Bayview landfill site and that is on
21 shale and I guess if I use my experience from Bayview,
22 I could say we have worked on shale, but this is part
23 of this hearing almost. 36 is the McKillop landfill
24 site which is on a clay. 37 is the Holmesville
25 landfill site and it is a clay base sand and gravel



1 pit. 38 was the Brock West landfill site which was in
2 a sandy till environment and has a bentonite liner
3 installed in portions of it, and 39 is the Spanish
4 River landfill site and we are looking for a very small
5 landfill site at the present time and are investigating
6 a sandy silt site.

7 Q. Could I take you back to paragraph
8 22 on page 11 and it looks like a typo but could you
9 correct that. That is listed as the Brantford landfill
10 site but the client is the same as 23, the Town of
11 Seaforth, and I assume we should change that to the
12 City of Brantford?

13 A. That is correct and as a matter of
14 fact I must say I got carried away and similar to the
15 typist, but perhaps you could also correct the date as
16 the dates for that should be 1976, 1981, 1987 to
17 present. If I may explain. In 1976 I took a modeling
18 of contaminant migration from the site as part of my
19 Masters work under our contract with Environment
20 Canada. In 1981 we undertook a small scale
21 hydrogeologic investigation and in 1987 to present we
22 are undertaking a much broader-scaled hydrogeological
23 investigation in support of expansion of this site.

24 Q. Mr. Crutcher, I am going to ask
25 you to sit down for a moment and I will ask Mr. Petrie



1 to go through his curriculum vitae and then we can pick
2 up on your direct experience at the Burlington/Bayview
3 landfill sites.

4 Mr. Petrie, continuing, in I guess the
5 latter portion of B-615, I will ask you also if you
6 would to number the pages in your report from 1 through
7 to whatever we get to so we can go back and forth if
8 necessary.

9 MR. PETRIE: A. I make it 1 through 6.

10 Q. Can I start again chronologically,
11 and the first entry I see, Mr. Petrie, is 1967-1969?

12 A. That is correct.

13 Q. I note you took your Bachelor of
14 Science in Geology from the University of Canterbury in
15 New Zealand?

16 A. Yes, a three year degree program,
17 '67 through to the end of '69.

18 Q. Then, picking up following your
19 graduation from the University of Canterbury, am I
20 correct that we go over to page 2 where you began your
21 employment experience as an exploration geologist in
22 the period 1970 to 1971?

23 A. Correct.

24 Q. Layton and Associates Ltd., in New
25 Zealand?



1 A. Correct.

2 Q. You were working in geological
3 mapping in rock and unconsolidated formations?

4 A. Associated with the exploration of
5 mineral properties.

6 Q. Continuing and if you could pick
7 up for us again after I guess two years as an
8 exploration geologist, I gather we go back to your
9 educational section of your curriculum vitae and you
10 went back to school for a period at the University of
11 Canterbury and obtained your Masters in Geology?

12 A. That is correct.

13 Q. We see in the entry 1971 to '74
14 you were back at school and obtained your Masters of
15 Science in Geology?

16 A. Correct, and it was a two-year
17 program, and I spent two and a half years doing a
18 rather elaborate thesis on some elements of structural
19 geology.

20 Q. If you would pick, if you would,
21 following obtaining your Masters, if you could back,
22 what employment did you then embark on?

23 A. I ended up in British Columbia,
24 Canada.

25 Q. Back at page 2, 1974?



1 A. Page 2, correct, and for the
2 latter part of 1974 I was employed as a mine geologist
3 in an underground copper mine in the northern part of
4 British Columbia, and my responsibilities were looking
5 at copper ore and its distribution underground and
6 keeping an eye on the ore grade so we were mining the
7 most valuable rock.

8 Q. Then you joined the B.C. Ministry
9 of the Environment, is that correct, in 1975?

10 A. At the beginning of 1975 for a two
11 and three quarter period or so where I was employed
12 with the British Columbia Ministry of the Environment
13 as a groundwater geologist.

14 Q. Could you be more specific. What
15 were your responsibilities for the B.C. Ministry of the
16 Environment as a groundwater geologist?

17 A. Much of my period at that time was
18 spent in evaluating and developing groundwater
19 supplies. The British Columbia government used to
20 undertake its own development of groundwater supplies
21 and so we did our own investigations and also our own
22 development, contracting drillers, undertaking pumping
23 tests, field mapping of the aquifers and existing wells
24 along with an evaluation of all the existing data.

25 The programs I worked on were



1 specifically aimed at developing municipal supplies and
2 irrigation supplies and to that end I had to evaluate
3 pumping tests, I looked at regional water level data
4 and regional groundwater quality data.

5 As part of the Ministry I was also
6 involved in an evaluation of problems with respect to
7 other consultants reports, reviewing existing data and
8 consultants reports for proposed sitings of industries,
9 developing water supplies, and some groundwater
10 contamination problems in the Gulf Coast of Vancouver
11 Island, on the Gulf Islands where there is salt water
12 intrusion because of the excessive groundwater demand
13 local to the coastline.

14 Q. You continued with the Ministry of
15 the Environment of B.C. until 1977 and if I go back to
16 page 1 I pick up an entry, 1977 - 1978 under education,
17 you were enrolled at the Hebrew University of Jerusalem
18 in Israel and obtained a diploma in groundwater
19 development?

20 A. Correct. When I left the British
21 Columbia government I was en route to Ethiopia to
22 undertake a project in conjunction with the Canadian
23 government and would at that time have been employed
24 with Associated Engineering Services in Vancouver.

25 However, there was a significant measure



1 of hostilities in the area for which I was targeted,
2 and no pun intended. At that time I digressed to
3 Israel where I undertook a nine-month course in the
4 development of groundwater supplies. Much of this
5 course was focused on arid groundwater development
6 which, in my case, was something I had not experienced.

7 At the termination of that course I
8 proceeded to Ethiopia as things had quieted down to
9 some measure.

10 Q. We see the last entry on page 1 is
11 1978 to 1981 and you are listed as a project
12 groundwater geologist with Associated Engineering
13 Services, a Vancouver-based firm; is that correct?

14 A. Correct, and we were on contract
15 to CIDA, the Canadian International Development Agency.

16 Q. You were actually located in
17 southern Ethiopia and involved in an evaluation and
18 development of groundwater resources?

19 A. Correct.

20 Q. How long were you there?

21 A. Two and a half to two and three-
22 quarter years.

23 Q. In 1981 we pick up in employment
24 that you returned to Vancouver, if I understand it
25 correctly, in 1981 where we have an entry of



1 groundwater geologist, Pacific Hydrology Consultants,
2 and is that a Vancouver firm?

3 A. A Vancouver firm and I was there
4 for a short period of time at the end of 1981.

5 Q. Then you went with Piteau and
6 Associates and is that a Vancouver firm?

7 A. That is correct.

8 Q. You were again a groundwater
9 geologist?

10 A. Yes. For both of those companies
11 I was most working with developing groundwater
12 supplies, municipal and industrial resources and
13 applications.

14 Q. Then if I understand it correctly
15 we go to the first entry on page 1 where you returned
16 to school, particularly to the University of Waterloo,
17 where you enrolled in a Master of Science program in
18 hydrogeology?

19 A. That is correct. I wish to
20 correct one thing where I have the statement "thesis"
21 and I have a title, but that was a project because I
22 did not do a thesis at the university but took the
23 optional course of doing a project and a large number
24 of courses. So the word "thesis" should be struck out
25 and "project" entered there.



1 Q. Could you explain what that
2 project was, "Field Response of a Clay Till in a
3 Layered Aquifer System..."?

4 A. Adjacent to the University or
5 beneath the University we have a till sequence and a
6 thick sand aquifer and this sand aquifer is in part
7 exploited by the municipality of Waterloo for their
8 water supply for the city. I investigated what
9 happened when we pumped or changed the pumping
10 condition within that aquifer and to that end I put a
11 large number of piezometers within the till on top of
12 the sand, and we changed the pumping condition in the
13 sand underneath which induced a series of differential
14 stresses, or water pressure changes within the
15 overlying till, and that gave us some measure of the
16 amount of water that went vertically down from that
17 till into the sand and thence to the pumping well as
18 opposed to the amount of water just passing laterally
19 through the aquifer to the pumping well.

20 Q. You were at the University of
21 Waterloo on your Master of Science program until 1984
22 and then am I correct that upon graduation you joined
23 Conestoga-Rovers & Associated Limited?

24 A. Correct. I finished at the
25 University in August of '84 and started at Conestoga-



1 Rovers in September of the same year.

2 Q. You are noted under employment as
3 a senior hydrogeologist with that firm?

4 A. Correct.

5 Q. You have indicated with three
6 hyphens the type of work generally that you have been
7 involved in?

8 A. Correct.

9 Q. Could you be more specific and
10 indicate what your responsibilities have been, and I
11 note as well you have listed a number of relevant
12 hydrogeologic experiences with waste disposals
13 beginning at the bottom of page 2 and continuing over
14 to page 6?

15 A. On page 1 I have listed three
16 general categories in which I am employed as a senior
17 hydrogeologist at Conestoga-Rovers, the first being
18 hydrogeologic investigations of municipal landfills and
19 hazardous waste sites in Canada and the USA, and the
20 second is hydrogeologic evaluation of remedial
21 alternatives at waste disposal sites. The third one is
22 design and performance evaluation of groundwater
23 remediation systems utilizing purge wells and lateral
24 collectors.

25 Much of the work that Conestoga-Rovers



1 does is of an engineering nature and the
2 hydrogeological work I do focuses in on the suitability
3 or applicability of various engineering options being
4 entertained for the clean-up of hazardous waste sites.

5 At the bottom of page 2 there is a
6 heading of relevant hydrogeologic experience with waste
7 disposal. On these two or three pages I have listed
8 some of the sites for which I have undertaken
9 activities and those sites of Ontario landfills have
10 entered here along with some of the sites for which we
11 have hydraulic remediation of hazardous sites in the
12 US. Hydraulic is involving leachate collection or
13 purge wells or some kind of hydraulic control as
14 opposed to other alternatives where you dig it up and
15 burn it or something.

16 Q. You have listed under each of
17 these numbered hydrogeologic experiences with waste
18 disposals, 1 through 15, there are one or two dots,
19 three in some cases indicating the type of work that
20 has been undertaken. Is this your specific work?

21 A. That is my specific work I have
22 undertaken or supervised with respect to the site in
23 question, yes.

24 Q. I notice over at page 3, item 6,
25 you were involved with the Bayview Park landfill site



1 in Burlington from 1986?

2 A. Correct.

3 Q. To the present?

4 A. Yes.

5 Q. Was that your first involvement
6 with the specific areas we have been discussing in the
7 proceedings here?

8 A. No. My first involvement on the
9 Bayview Park ... I am sorry, my first involvement in
10 the hearings here was in conjunction with the
11 Conestoga-Rovers response to the Stage 2C document
12 prepared by the Region of Halton, and that would have
13 been in 1985.

14 Q. In 1986 you became more involved
15 in the Bayview Park landfill site specifically?

16 A. Correct.

17 Q. As listed. You have also
18 continued as I understand it in examining the documents
19 such as the Trow reports and so on before the Board?

20 A. That is correct.

21 DR. KINGHAM: Can you back up? You said
22 Conestoga-Rovers response to the Stage 2C and can you
23 explain that?

24 MR. PETRIE: Yes. The Stage 2C
25 documents provided a summary of the investigations at



1 that point in time, being January 1985 with respect to
2 the hearing we are now engaged in. I reviewed those
3 documents on behalf of the City of Burlington and there
4 was a Stage 2 response document prepared by Conestoga-
5 Rovers and Ecoplans, a second consultant, to the City
6 of Burlington and part of that response entailed
7 hydrogeology being the Trow reports referenced by
8 Mr. McQuaid.

9 DR. KINGHAM: For the City of Burlington
10 and to refer back to the Regional Municipality of
11 Halton?

12 MR. PETRIE: Correct.

13 MR. MCQUAID: Q. Mr. Crutcher, could
14 you pick up for us in this history what your first
15 involvement was with respect to the various sites we
16 have been referring to, the proposed sites, Burlington
17 or Bayview, and could you go through your direct
18 involvement?

19 MR. CRUTCHER: A. In a minute. For my
20 direct involvement in the area of Burlington/Bayview we
21 were retained in early 1984 by the City of Burlington
22 in conjunction with the firm of Ecoplans Limited to
23 advise the City in reviewing the environmental
24 assessment to be undertaken by the Regional
25 Municipality of Halton in locating a landfill site and



1 in addition, we advised the City on the hydrogeology
2 aspects of the then proposed expansion to the
3 Burlington landfill site.

4 Our initial involvement in 1984, or the
5 majority of work undertaken in early 1984 dealt with
6 the Burlington landfill expansion because it was quite
7 imminent and the Halton landfill site was a little
8 delayed or going a little slower, and now where we are
9 in 1988.

10 Q. Initially your direct involvement,
11 Mr. Crutcher, was with respect to the proposed
12 expansion by the Region of what has been referred to as
13 the northerly part of the Burlington site?

14 A. That is correct.

15 Q. Subsequently did you then become
16 more involved as well in the process of finding the two
17 sites which are now before the Board, Sites D and F?

18 A. Essentially after that time we
19 monitored the work being undertaken by the Region and
20 quite actively reviewed the draft reports prepared by
21 the various consultants at the Stage 2C level and then
22 prepared our report in conjunction with Ecoplans on the
23 response to that draft 2C document, which I believe was
24 prepared in something like March of 1985.

25 Q. Since the retainer by the City in



1 March of 1985, has CRA been continually involved in
2 evaluating the various reports that have been
3 submitted?

4 A. Yes, we have been very actively
5 involved throughout the period essentially since about
6 1984 with monitoring and undertaking independent work
7 on behalf of the City of Burlington and we have been
8 dealing, as I indicated with the Burlington landfill
9 site, very much with the Halton environmental
10 assessment, and the Bayview Park landfill site and
11 dealing firstly with the investigation of contamination
12 and remediation.

13 Q. I won't turn specifically at this
14 point, but do I understand you have been involved, you
15 and/or Mr. Petrie and he can add if he would at the end
16 of your answer, but have you reviewed all the various
17 documents which we have heard reference to, the
18 hydrogeologic, hydrology reports and so on, over the
19 period of time?

20 A. Yes, at one time or another I have
21 reviewed all the reports and they are very extensive
22 and whether they will be utmost on my mind is a big
23 question, but I have reviewed all of them at one time
24 or another.

25 Q. Mr. Petrie, can you confirm that



1 you have also reviewed the various reports which have
2 been listed and filed as exhibits from time to time?

3 MR. PETRIE: A. I have reviewed the
4 hydrogeological reports.

5 MR. McQUAID: That completes my review
6 of the resumes and curricula vitae and I would like to
7 tender these two gentlemen as the panel of witnesses
8 who will be dealing with the City of Burlington's
9 hydrogeological evidence.

10 MR. LANCASTER: Certainly.

11 MR. McQUAID: Then it would be my
12 proposal ...

13 MR. LANCASTER: Should we first have our
14 break, because it is going on to eleven.

15 MR. McQUAID: If this would be a
16 convenient time?

17 MR. LANCASTER: Fifteen minutes.

18 ---Recess

19 MR. LANCASTER: Please be seated.

20 MR. McQUAID: Q. Mr. Petrie, you have
21 brought to my attention one small heading change you
22 would like to make to your CV at page 3 of your portion
23 of the document, item 2, where there is reference to
24 the Highway 48 landfill site?

25 MR. PETRIE: A. That is correct, and it



1 should be entitled "Stouffville Landfill Site".

2 Q. The same terminology Mr. Crutcher
3 used back at page 8, item 7, Stouffville Landfill Site?

4 A. Stouffville Landfill site,
5 correct.

6 Q. Mr. Crutcher, I would like to
7 begin with you and particularly your initial
8 involvement in the study of the area. If I could ask
9 you to just put up the aerial for Site F. You
10 indicated to the Board that I gather you were the
11 initial person at CRA who was involved in terms of any
12 work in the general area?

13 MR. CRUTCHER: A. Correct.

14 Q. Particularly as a result of the
15 Region's application to expand the Burlington landfill
16 site?

17 A. That is correct. I acted as the
18 project manager for CRA for all the work CRA has done
19 for the City of Burlington.

20 Q. Could you explain the
21 circumstances again as to what your retainer was and
22 what work you undertook back in 1984?

23 A. As I indicated initially, we were
24 interviewed by the City of Burlington for providing
25 technical services and reviewing the Halton



1 environmental assessment, and shortly after we had a
2 joint retainer with Ecoplans and ourselves. The City
3 asked up to review the application for the Burlington
4 landfill site, and in fact the first piece of work we
5 did was dealing with the Burlington landfill site and
6 not the Halton environmental assessment.

7 Q. Could you explain what work was
8 undertaken and what recommendations you made to the
9 City during the course of that study?

10 A. If I may refer to the aerial
11 photograph labelled as M-103, the proposal by the
12 Region of Halton was for the expansion of the
13 Burlington landfill site and our involvement was
14 reviewing that proposal which was essentially taking
15 the northern or roughly the northern third of the site
16 and seeing if that was hydrogeologically suitable for
17 expansion.

18 In addition, the proposal also entailed
19 the filling in of the lower lying lands in the central
20 portion of the then existing landfill site, and we also
21 commented on that particular aspect.

22 Q. Before I get into the specifics of
23 the areas and so on, I asked you if you could, just in
24 reviewing the documents, give us an inventory of what
25 areas we are talking about when we talk about the



1 Burlington site, Site F and the Bayview site as well.
2 Could you give us a summary of what you understand the
3 areas and the tonnages are?

4 A. As per Mr. McQuaid's request, we
5 compiled together the areas and the volumes or amount
6 of refuse in place for each of the sites and perhaps I
7 could just write it up on the board here.

8 Q. All right.

9 A. What I am indicating is that for
10 the three sites, that being Bayview, Burlington and
11 Site F, the area in hectares and the volume in metric
12 tons or tonnes.

13 For Bayview, the area is approximately
14 15 hectares and you may note these are all approximate
15 values and I rounded them off. The in-place or number
16 of tonnes is very difficult to estimate because there
17 was no measure at the time and we undertook to do some
18 cross-sections on the site in order to get a feeling
19 for the amount of waste in place and we approximate 0.6
20 to 0.8 million, and I will be writing them as in
21 millions.

22 For the Burlington landfill site, the
23 area of landfilling, and I should refer to the area of
24 landfilling and not the total area of the site, but for
25 Burlington the area of landfilling is approximately 29



1 hectares and it has approximately 1.5 million tonnes in
2 place.

3 For Site F, the proposed area is
4 approximately 50 hectares, and it is proposed for 3.8
5 million tonnes.

6 Q. All right. Now, we had filed
7 earlier in the proceedings a map, and I think it was a
8 portion of Exhibit B-217 and the map was marked as
9 B-217A, if you could just put that up to the left.
10 Since we have those numbers on a tear sheet, perhaps I
11 could ask that that be marked as an exhibit.

12 MR. LANCASTER: That will be B-619.

13 ---EXHIBIT NO. B-619: Chart-area and volume of
14 Bayview, Burlington & Site F

15 MR. McQUAID: Q. On B-619 you have
16 noted the Burlington site as being 29 hectares and the
17 number of tonnes representing about 1.5 million. Can
18 you relate that to B-217A and, more specifically, what
19 area was it that was being proposed to be expanded on
20 when you became involved in 1984?

21 MR. CRUTCHER: A. I am referring to
22 B-217A and the northern portion of the site as depicted
23 on this plan is the lighter tone shown on the plan and
24 it is the areal expansion of the site and within the
25 central portion of the site it was a vertical
expansion, over waste that was presently in place.



1 Our review on the hydrogeological
2 aspects was primarily dealing with the northern and
3 just commenting on placing further waste here.

4 Q. What area was proposed either in
5 terms of hectares or tonnes when you were asked to look
6 at it in 1984?

7 A. The area of the northern section
8 of the site was approximately 7 hectares of land.

9 Q. What tonnage was expected or
10 anticipated to be filled?

11 A. Approximately a half a million
12 tonnes would be placed with that expansion.

13 DR. KINGHAM: I wonder for the ease of
14 future communications, can we agree that when you say
15 "tons" it will be metric tons unless you say otherwise
16 because we get into tonnes and tonnes and what have
17 you, so let's just call them tons and if you ever use
18 Imperial let us know?

19 MR. CRUTCHER: I will, but unfortunately
20 I think in Imperial and so sometimes I may be switching
21 back and forth without really knowing about it, but I
22 will attempt to do that.

23 MR. McQUAID: Q. Can you indicate to
24 the Board specifically when you were first retained by
25 the City and what you were asked to do and what



1 recommendation did you end up giving the City?

2 MR. CRUTCHER: A. When we were first
3 retained, and as I indicated we thought it was to deal
4 with the Halton environmental assessment, and we were
5 provided with the Halton documents and the first
6 request was for producing an opinion which was dealing
7 with the Burlington site.

8 We inquired as to what the City's
9 position in all matters were so we could get a feeling
10 for what our client was all about and where they were
11 coming from, and essentially their position was that
12 they had had a landfill in this vicinity for a
13 considerable length of time and they didn't
14 particularly want to have a landfill here anymore and
15 that was essentially their position. It was not a
16 technical position but a position indicating what their
17 preference was.

18 I indicated to the City that while I
19 could most certainly understand their position, we
20 could only provide expertise on technical matters and
21 they would have to take it the way it came and that was
22 fine by the City and they dealt with it.

23 In reviewing the Burlington landfill
24 applications as prepared by Dillon and their sub-
25 consultant Gartner Lee, we had a considerable number of



1 comments on the sites, or on the expansion of the site,
2 but essentially our recommendation to the City was to
3 support the application for the expansion of the site
4 because we believed the expansion to the northern
5 portion of the site was hydrogeological suitable.

6 We did recommend some design amendments
7 to the site as we discussed with the Region and they
8 subsequently were incorporated within the design of the
9 site. Our major criticism of the application really
10 did not deal with the hydrogeology so much -- pardon
11 me, the hydrogeology of the northern area so much as
12 dealing with the chemistry and definition of the
13 contaminant plume from the then existing Burlington
14 landfill site and we felt that the position taken by
15 the Region's consultant, Gartner Lee, could not be
16 defended and we did not believe that the chemistry was
17 representative and we recommended to the City and
18 subsequently to the Region that a much more
19 comprehensive monitoring program be undertaken at the
20 site. That was agreed to by the Region and put forward
21 to the Environmental Assessment Board at the hearing
22 which was held in 1984.

23 That recommendation, therefore, carried
24 through and, in fact, some of the reports which the
25 Board has now seen dealing with the Gartner Lee plume



1 delineation emanated from that origin, I do believe.

2 Q. Let me go back to ask you, you
3 indicated in answering the question that you
4 essentially gave a recommendation to support the
5 application and that the northerly portion was
6 hydrogeologically suitable. Could you be more
7 specific. What was there in terms of presence of strata
8 or whatever that led you to the conclusion that you
9 could make the recommendation to support it?

10 A. Our experience with landfill sites
11 up to that time had primarily dealt with overburden
12 materials and we had not been involved in dealing with
13 bedrock and fractured bedrock and shale and I should
14 say that when I say "our" it was the team that I
15 directed, but the firm as a whole had some experience
16 dealing with bedrock, but it does not come into our
17 routine per se.

18 We were uncomfortable on our
19 understanding of the shale and the work that had been
20 done to date, recognizing that this was 1984 and much
21 of the detailed studies had not been undertaken at that
22 time. The Hewetson report, or Hewetson thesis was not
23 out, the Hydrology Consultants report and work had not
24 been undertaken at that time, and so the information
25 available was essentially the Morrison Beatty work and



1 some work that Dr. Cherry had done and Dr. Cartwright
2 on reviewing that work.

3 We were quite uncomfortable with the
4 understanding of the site and felt that if landfilling
5 was to proceed directly on shale, it would be very
6 difficult for us at that time to support. You must
7 recognize that the amount of time we had to review this
8 was fairly limited, something in the order of a month
9 or two prior to the hearing.

10 However, the proposal that was put
11 forward by the Region was in fact not to landfill on
12 shale and the proposal was to leave a cap over the
13 expansion area of a minimum of 1.5 metres of the clay,
14 native clay till.

15 So, from our assessment we felt the
16 primary barrier to contaminant migration from the areal
17 expansion of the site was in fact this clay barrier and
18 not the shale itself and so our emphasis on review
19 dealt with reviewing the integrity of the clay till
20 rather than the shale itself.

21 It was in fact on that basis that we
22 recommended to the City of Burlington to support, with
23 some qualifications, the expansion of the site and, in
24 fact, the City subsequently did that and put forward
25 their position at the hearing.



1 Q. Was this in the fall or early
2 winter of 1984?

3 A. I believe it was actually in the
4 spring of 1984.

5 Q. Sorry. Can I ask you to just pick
6 up what was your next involvement in terms of either
7 the process or the Bayview site?

8 A. The City then got us back on track
9 to deal with the Halton environmental assessment and
10 asked us to comment on what would be the capacity of
11 the landfill site if in fact it was placed at Site F.
12 They wanted to get a feeling for whether or not Site F
13 had a chance of being feasible for the Region and
14 should they invest considerable resources into
15 reviewing this proposal and so they asked us to do a
16 very preliminary assessment of the capacity of that
17 available land to place waste on and so we prepared a
18 very short report dealing with that.

19 Ecoplans who worked in conjunction
20 prepared a report dealing with the biophysical nature
21 of the site and that report was subsequently filed with
22 the City. Then, the Region prepared their 2C
23 documentation which was quite extensive and we were
24 asked by the City to review as much of that document as
25 we felt capable of reviewing and commenting on and so



1 in fact we did a comprehensive review, not only of the
2 hydrogeology, but of other matters contained within the
3 2C documents, the most notable being the ranking
4 procedure for the selection of the site.

5 Q. Could you pick it up
6 chronologically and when is this and where does this
7 take us in terms of period of time?

8 A. The 2C documents I believe were
9 produced in early 1985 and our response document was
10 produced, and I can just check, on March 25, 1985. At
11 that time we represented the work we had done to the
12 Region and Regional Council and the Region then
13 proceeded to develop a work plan for undertaking their
14 Phase 3 work program which, from our perspective, was
15 undertaking the detailed hydrogeological investigation
16 into the site and the preparation of the conceptual
17 design plans.

18 We commented on the work plans and then
19 proceeded to review what documentation was made
20 available over that period of time.

21 Q. At some point you were also, as I
22 understand it, retained to look at the Bayview site as
23 well?

24 A. Yes. In 1985 the Ministry of the
25 Environment wrote a letter to the City of Burlington



1 indicating concern with respect to surface water
2 contamination emanating from what they believed was the
3 Bayview landfill site. Now, if I may refer to this
4 aerial photograph M-130 ...

5 Q. I believe it is M-103.

6 A. M-103. As you can see I am good
7 at transposing numbers. The City or the Ministry of
8 the Environment had been monitoring some of the
9 intermittent streams downgradient of the Bayview
10 landfill site and sent a letter to the City of
11 Burlington indicating that they found contamination in
12 those streams and they felt the City should undertake
13 an investigation of the source of this contamination
14 and what remediation activities could be taken at the
15 Bayview landfill site.

16 We were then retained by the City of
17 Burlington to review the source of the contamination
18 and subsequently provide alternatives for remediation,
19 the conceptual design, the design of a leachate
20 collection system and subsequently the construction.

21 Q. Could you indicate to the Board
22 where the construction actually took place and what its
23 nature was?

24 A. If I may, prior to that, our
25 report on the contamination indicated that, yes, we had



1 contamination emanating from the Bayview landfill site
2 and it was evidenced in bacteria contamination as well
3 as some inorganic and, to some extent, some organic
4 contamination, essentially at the toe of the landfill
5 site on the southern portion of the Bayview landfill
6 site.

7 Further downstream that contamination
8 was not nearly as evident and to some extent you would
9 find minor occurrences but not particularly high levels
10 of contamination and with the exception of bacteria.

11 At that time it was peculiar to us to
12 find bacteria contamination because that is not
13 normally associated with the landfill, but we had fecal
14 coliform contamination and so we undertook a more
15 extensive investigation, both upstream and downstream
16 of the landfill site to in fact determine where the
17 bacteria contamination was. In fact, the whole area
18 has to some degree some bacteria contamination
19 emanating both from the upstream and downstream
20 sources.

21 The City of Burlington subsequently
22 undertook their own investigation of sources within the
23 City built-up areas and identified some misconnected
24 sewers and we were retained to provide advice on what
25 options were available for controlling the landfill



1 site itself.

2 Our recommendations to the City were
3 somewhat complicated because a portion of the landfill
4 site was not on land owned by the City of Burlington,
5 and in fact there had been some minor encroachment of
6 the landfill onto NSP property and in fact if we were
7 to construct a leachate collection system to collect
8 the seepage, much of that system would be required to
9 be on NSP property.

10 There were considerable discussions
11 between the City and NSP and, to some extent, the
12 Ministry of the Environment on how we would go about
13 doing this and eventually an agreement was struck that
14 in fact we could install a leachate collection system
15 along the western boundary of the Bayview landfill site
16 and in the valleys of the southern portion of the
17 Bayview landfill site.

18 The topography along the southern side
19 is quite variable and in fact it was not practical to
20 install a system completely across the bottom of the
21 site, but only in the valleys.

22 Q. Is it a toe leachate system and is
23 that the correct terminology?

24 A. That is essentially correct.

25 Q. Is that leachate system now



1 constructed roughly along the red line we see running
2 along the southerly portion of the Bayview site on
3 M-103?

4 A. That is correct, and you can see
5 it varies to some degree, but the majority of the
6 system is actually installed on NSP land just due to
7 the nature of the topography in the area.

8 Q. Is that line roughly then as you
9 understand it the division of ownership between the
10 Bayview site and the NSP land immediately to the south?

11 A. That is correct, and due to the
12 scale of this aerial I suspect that we would not be
13 able to see the actual boundary changes where the
14 encroachment occurred with the waste.

15 Q. CRA designed and oversaw the
16 construction of that toe leachate system, did it?

17 A. Correct.

18 Q. When did that occur?

19 A. That was designed and constructed
20 in 1986 and in fact went into operation, I believe, in
21 December of 1986.

22 Q. Could you give the Board an
23 approximate cost of construction of the facilities that
24 were required to be installed?

25 A. I believe the cost was just over

rie

\$1 million, the complete system. Much of the cost was based on the need to connect to a sanitary sewer and that was some distance from the landfill site and a forcemain and gravity system was constructed from the Bayview landfill site and crossing Highway 403 and connecting into the sanitary sewer just south of Highway 403.

Q. So that went into operation in the early part of 1987, the latter part of 1986?

A. That is correct. I may add that the system was designed to collect the surface seepage and very shallow groundwater. We were concerned at that time that in fact we could not demonstrate to any regulatory body, or essentially to any person, that in fact the system we would construct would deal with any of the deeper groundwater flow.

We had allowed within the design sufficient room to put in what we referred to as a cutoff wall, being a means of putting a slurry wall or something around the site if in fact it was determined that groundwater contamination was unacceptable and further remediation work would be required at this site. That was put into our definition of the area required.

We also recommended to the City that in



1 fact the landfill sites should have a downgradient
2 contaminant attenuation zone. We were uncomfortable
3 with our knowledge of the contamination emanating from
4 the landfill site and at that time the Hewetson thesis
5 had just been released and it indicated low level
6 contamination to as deep as 30 metres downgradient of
7 the landfill site.

8 While we had many questions about the
9 thesis and the work undertaken, we felt that the site
10 would benefit greatly from having what we referred to
11 as a downgradient contaminant attenuation zone. The
12 City asked us to define what we meant by that
13 terminology and what we indicated was that to have
14 essentially the legal right to use the downgradient
15 lands from the Bayview site for attenuation of the
16 contaminations, and in fact if we were looking for an
17 evaluation of the performance of the landfill site and
18 saying whether it meets acceptable standards, we would
19 be meeting it at the downgradient edge of the
20 contaminant attenuation zone rather than at the
21 property boundary.

22 We advised the City at that time we
23 could not define exactly the extent of the zone we
24 needed because it was a very difficult task, but we
25 felt it would be wise to see if you could acquire,



1 completely acquire the right, not necessarily
2 ownership, but acquire the right for the contamination
3 attenuation zone down to the North Service Road.

4 We also indicated that at a minimum we
5 felt that acquiring down to the base of the swamp area
6 would suffice from the information we had and
7 subsequently the City undertook to obtain legal rights
8 for the contaminant attenuation zone approximately
9 halfway down the NSP property, which was the base of
10 the swamp area.

11 Q. About half the distance from the
12 southern limit of the Bayview site to the North Service
13 Road?

14 A. That is correct.

15 Q. You referred to the base of the
16 swamp area. Is there some feature on M-103 that you
17 can point to as what you mean by the base of the swamp
18 area?

19 A. It is not particularly evident on
20 the aerial, but what we did is, we walked the site and
21 found where the wet marshy areas were, and that is
22 essentially half of the distance between the Bayview
23 site and the North Service Road, and we actually staked
24 the area where we were seeing some groundwater
25 discharge.



1 Our rationale for indicating that as a
2 minimum was that we felt there was some groundwater
3 discharge at this location and in fact it may pass the
4 leachate collection system we installed due to just
5 going underneath that system and discharging in this
6 area (indicating) and the swamp would provide a natural
7 means of treatment of that leachate.

8 So, it was advantageous to have that
9 swamp for biological treatment of any contaminated
10 groundwater. We felt that that would provide a very
11 positive means of dealing with the site, and
12 recognizing that we were looking at long-term liability
13 of the site and performance of the landfill site under
14 quite strict scrutiny by the Ministry of the
15 Environment.

16 Q. You indicated the City undertook
17 to acquire rights in that particular parcel of land?

18 A. Yes, they proceeded to expropriate
19 that portion of land.

20 Q. I realize it's from a layman's
21 viewpoint, but could you indicate what, if anything,
22 has happened to that particular endeavour?

23 A. I am pleased you said from a
24 layman's point of view because I never did completely
25 understand the overall process, but we in conjunction



1 with an Ontario Land Surveyor located the land we were
2 talking about and the City undertook proceedings for
3 expropriation.

4 NSP and subsequently the Town of Milton
5 opposed that expropriation and somehow I believe it is
6 in the courts someplace which I can never figure out.
7 We had one discovery hearing before the Town of Milton
8 on the expropriation and I honestly don't know the
9 status beyond that.

10 Q. In terms of CRA's involvement on
11 that portion of the land or on NSP land, can you
12 indicate what, if any, agreements or monitoring or
13 whatever had your firm undertaken with respect to the
14 land downgradient of Bayview?

15 A. As part of the overall leachate
16 collection system and performance evaluation, we
17 recommended and subsequently undertook a fairly
18 comprehensive monitoring program of the site. The
19 purpose of the monitoring program was to firstly define
20 if in fact the leachate collection system was operating
21 correctly and, in fact, is controlling the toe
22 discharge of leachate from the landfill site.

23 The first report on that is dated in
24 1987 and dealt with the 1986 monitoring and since the
25 leachate collection system was in fact not constructed



1 until the end of 1986 it really did not deal very much
2 with the performance but documented more what was the
3 existing situation at the site.

4 The subsequent report which is what we
5 referred to as our 1987 monitoring report, a draft of
6 that report has just recently been completed and
7 shortly we will be completing the final, but that
8 report dealt with -- or the majority of the report
9 dealt with surface water monitoring at the site, both
10 upgradient and downgradient and assessing the
11 differences between pre and post-leachate collection
12 system, and essentially the bottom line indicated that
13 the leachate collection system was operating quite
14 effectively.

15 We were also attempting to undertake a
16 water balance on the site and trying to get a better
17 feel for the amount of leachate we were dealing with
18 and how much was being discharged to the leachate
19 collection system and how much may potentially is being
20 discharged or exfiltrating into the groundwater.

21 However, we were unsuccessful on that at
22 the present time due to some mechanical problems with
23 the flow metering devices and that is being rectified
24 by the City of Burlington at the present time.

25 Q. All right.



1 A. We had recommended to the City to
2 undertake a limited groundwater monitoring program as
3 well. In 1986 we recommended that we await the reports
4 of Hydrogeology Consultants and see what information
5 they had so we could develop a monitoring program and
6 so in fact we did no active monitoring of the
7 groundwater in 1986, but in 1987 we did some select
8 monitoring of some observation wells downgradient of
9 the landfill site, the results of which are presented
10 in our 1987 monitoring report.

11 Q. We will come back to that later on
12 in the evidence. Now, I would like to ask you,
13 Mr. Crutcher, to go to what I think has been marked as
14 B-617, the hydrogeologic report on Site F and turning,
15 if we could, to the introduction at page 1, I guess
16 three pages before Tab A, we see -- Tab A.

17 As I understand this report, this
18 summarizes the results of the various hydrogeological
19 studies that you and Mr. Petrie have undertaken with
20 respect to Site F?

21 A. That is correct.

22 Q. Could you just, beginning at the
23 introduction, could you explain how CRA approached the
24 problem and what it was you were looking for when you
25 were examining these various reports on Site F in



1 particular?

2 A. Since we had been involved in the
3 overall process since about 1984, we had been exposed
4 to a considerable amount of information and we had
5 expressed an opinion on that information throughout the
6 period of time. We had difficulty in trying to compile
7 a report together that would comprehensively put our
8 opinion forward and make it quite legible and
9 understandable because of the way these proceedings
10 have been conducted.

11 We have had the opportunity of reviewing
12 virtually all the previous reports up to the Trow
13 submission of their final report on the hydrogeology,
14 and then have reviewed the subsequent information on
15 hydrogeology through the Milton witnesses and such.

16 So, we made a decision on how it would
17 be best to present our reports that would be concise
18 and hopefully easily readable and efficient, if I may
19 use that word.

20 We divided the reports into three
21 sections, part A, B and C. Part A is where we
22 attempted to define what we mean by hydrogeologic
23 suitability. We were essentially setting a generic
24 definition in part A for each item and subsequently we
25 would test the work undertaken and the comments against



1 that definition. Since it is essentially generic, part
2 A is actually common to both Site F and Site D.

3 In part B of the report, it is entitled
4 "Critique of Technical Studies" and in fact it is in
5 fact reviewing the Trow report and, to some extent,
6 some of the work the Milton consultants have undertaken
7 and commenting on it directly.

8 We did not expand into that in our
9 opinion on what we felt it indicated, but in fact just
10 commented on the work that had been undertaken and so
11 part B is commenting or critiquing directly the
12 reports.

13 Part C is in fact what we called, and I
14 am referring to Site F, Exhibit B-617, but it is our
15 interpretation of the Site F hydrogeology and, in fact,
16 it incorporates many of the comments we have provided
17 in part B, but in fact is our opinion.

18 We noticed as the course of these
19 hearings proceeded that it was difficult to determine
20 when you were doing a comment versus an opinion. We
21 have attempted to break the two out and part B is our
22 comment and part C is our opinion.

23 As you can probably appreciate, that is
24 to some extent difficult to separate out at all times
25 and so there is some overlap, but we have attempted to



1 do that.

2 Q. I refer you to pages 2 and 3 of
3 the introduction and there we see a list of reviews of
4 studies and various reports, major reports that I
5 gather you and Mr. Petrie have examined in order to
6 testify?

7 A. That is correct. It is more of a
8 listing of the work that has been undertaken rather
9 than a listing of the reports per se, because there are
10 a number of reports under each item in some cases.

11 Q. I see on page 3 you have put in
12 writing the summary you have just indicated with
13 respect to parts A, B and continuing over to page 4,
14 part C where you note that part C contains your actual
15 CRA interpretation of the site following the various
16 investigations and reviews undertaken?

17 A. That is correct.

18 Q. Turning to part A, page 5 in the
19 exhibit, we see a heading "Definition of Site
20 Hydrogeologic Suitability for Landfilling" and we see a
21 listing of five items. Can you just explain why you
22 are listing those?

23 A. Well, in part in answering that
24 question I would like to talk about the section and how
25 we went about it, about preparing it. In discussions



1 on how we should prepare it, and it was primarily with
2 Mr. McQuaid and representatives from the City of
3 Burlington, we felt that the definition of
4 hydrogeologic suitability was a moving target, or
5 appeared to be a moving target and everybody sort of
6 used different terminology.

7 Essentially the basis of hydrogeologic
8 suitability in our opinion was the fact that to
9 determine that the site would not cause and add inverse
10 impact, both from a technical and to some extent a non-
11 technical basis. Mr. McQuaid asked us to attempt to
12 document that in some fashion, and in fact -- so a lay
13 person could understand what we were talking about --
14 and so we prepared what we called part A of this report
15 on that basis.

16 We prepared it saying how do you go
17 about doing a hydrogeologic investigation and what are
18 you testing for, and in fact we presented -- undertook
19 a considerable effort to put this together, hopefully
20 in a concise and fairly definitive method.

21 On the five items listed on page 5, if I
22 may read them, the first indicates that to undertake or
23 to determine the hydrogeologic suitability, one must
24 first have an understanding of the hydrogeologic
25 setting, and again I will be explaining in more detail



1 what each of these items means subsequently. Once you
2 have a good understanding of the hydrogeological
3 setting, then you will make a determination of the
4 level of engineering necessary to place a landfill site
5 in that area.

6 That may be somewhat iterative with item
7 1, meaning the level of engineering may indicate that
8 in fact our understanding of the hydrogeology would be
9 better enhanced by doing additional hydrogeological
10 investigations and so there is some iteration between
11 the design and the hydrogeology. If I may make an
12 example, if in fact I was establishing a site where I
13 would have a discharge of leachate coming from that
14 site, then I must know ways of assessing that discharge
15 being acceptable, and in fact if our understanding of
16 the hydrogeological setting was such that that
17 discharge would not be monitored or you could not
18 predict, additional hydrogeological work would have to
19 be undertaken to do that.

20 We think it is very important to
21 integrate the engineering with the hydrogeology and in
22 fact our firm has done that through the way we have set
23 up the structure of the firm such that the two
24 disciplines are integrated such that when you come out
25 at the end of a design, you can then get into a



1 definition of boundary impacts which is our third item.

2 The boundary impacts are based off the
3 design of the site. Once you have a design of the site
4 we then superimpose the landfill on the site and
5 predict what will happen in the future.

6 It is also necessary to develop a
7 monitoring program and that monitoring program is to
8 assess the performance of the site against our
9 predictions and, subsequently, a contingency plan. As
10 we are all aware from having sat through all the
11 hydrogeological testimony, hydrogéology is not as
12 definitive a science as one would like and there are
13 possibilities that in fact our predictions will not be
14 made and the contingencies will need to be implemented
15 and so in fact we must assess the contingency plans to
16 ensure that in if fact problems do develop, we can
17 engineer around those problems.

18 Now, taking that procedure for
19 undertaken a hydrogeologic suitability, we then had to
20 test that on what we are looking for when we say a site
21 is hydrogeologically suitable. If you refer to page 6
22 and paragraphs (1), (2) and (3), they are essentially
23 our summary of what we term as a hydrogeologically
24 acceptable or suitable landfill site. We refer to this
25 as the minimum criteria.



1 Firstly we indicate that the migration
2 of contaminants from the landfill site must be
3 predictable. You will notice that we have underlined
4 what we have considered to be the key words, and the
5 impact from this migration must be determined to be
6 acceptable. The two key words there are "predictable"
7 and "acceptable". Predictable is what comes out of the
8 hydrogeologic investigations, essentially the design of
9 the site, and one must be able to predict what is going
10 to happen in the future.

11 Acceptable is a very difficult term to
12 define and in fact I believe that a lot of the decision
13 of this Board is really going to be based on what is
14 acceptable.

15 We have been involved or I personally
16 have been involved in landfilling in Ontario on a
17 professional basis since approximately 1977 and that
18 terminology "acceptable" has changed almost on a yearly
19 basis. What is acceptable in 1988, or what was
20 acceptable in 1977 may not be what is acceptable in
21 1988. In fact there are many cases that say that. We
22 have very much an evolving science and therefore it is
23 necessary to always look at what is the terminology
24 acceptable, and look at it in a much broader term than
25 strictly what we are technically assessing.



1 Q. Can I stop you there and ask you
2 if you can be more specific in terms of giving us an
3 example. What do you mean what might have been
4 acceptable in 1977 may not be in 1988? Are there any
5 examples in this area, for example, that you can give
6 us?

7 A. Well, if I may go back a little
8 prior to that, in 1971 the province of Ontario enacted
9 the Environmental Protection Act where in fact they
10 dealt with landfill sites and started to regulate them
11 on a more active basis, but in fact there was very
12 little enforcement of that. In 1977 the Ministry of
13 the Environment had, in fact, and this of course is in
14 my opinion and the Ministry of the Environment may have
15 a different opinion, but the Ministry had very little
16 enforcement on landfill sites and in fact sites were
17 being located or expanded into areas where the
18 permeability of the base soils was much higher than
19 what we are dealing with in 1988 and in fact
20 contamination and prediction of contaminant migration
21 was not really undertaken. It had been undertaken at a
22 research level, and in fact that is what I took my
23 Masters thesis on, but when I went to apply what I felt
24 was my trade at the time, I found that the practice was
25 that very little of this was being done, it was



1 expensive and nobody was really requiring it.

2 So, in fact the modeling aspects, if I
3 could use that as an example, didn't really get in to
4 the applied basis until later in the 1980's. I would
5 say in the early 1980's awareness of landfilling and
6 the enforcement of the Environmental Protection Act
7 came much more into being and the Ministry of the
8 Environment got more active and in fact the reviews of
9 sites was more critical and the public became much more
10 aware.

11 On that basis the need for definition of
12 what the prediction from a landfill site, what
13 contaminants would discharge from the site increased
14 and in fact on doing that work, the assessment of the
15 hydrogeologic suitability therefore increased, and in
16 fact it tightened up and it was required when we looked
17 at a silt site, we would now tend to look more to a
18 clay site and that has continued through.

19 It used to be, and I can recall that if
20 we had a site which had a soil of something like a 10^{-6}
21 centimetres per second we thought we had a pretty good
22 site to landfill on and then we carried on a little
23 longer and we ended up being with 10^{-7} as being the
24 standard to look for for landfilling, and now we are
25 aiming, if we are not there, at 10^{-8} soils and saying



1 that this is what we are looking for landfilling.

2 Obviously I am generalizing and we must
3 look at specifics, but that is more the trend in the
4 industry and that has to be reflected when you are
5 reflecting what is an acceptable landfill.

6 If you look through my curriculum vitae
7 and the sites and what they are situated on, there is a
8 fair change in the soils and they go from silts into
9 clays and into more engineered sites and that is more
10 of a reflection of how the industry is proceeding and
11 how the regulatory bodies are proceeding.

12 So, if I could relate that back to
13 acceptable, we have to consider what acceptable is in a
14 broader term and in more current standards.

15 The Ministry of the Environment
16 attempted or has, and again I will let the Ministry
17 attest to their own policies, but has presented a
18 document called the "Reasonable Use Policy". That
19 came out in 1986 and has been used as guidance on
20 determining what is, what I refer to as technically
21 acceptable. However, within the document, the Ministry
22 also indicates that in fact public interest is very
23 much a part of acceptable.

24 As a person who must advise many clients
25 on acceptable, I deal with both issues. You can say a



1 site is hydrogeologically suitable, but that is from a
2 technical perspective and also from a public interest
3 perspective. You must look at it and say can you
4 defend what you are putting forward as public as being
5 acceptable and you must be able to predict what is
6 going on at the site and be able to monitor it and you
7 must be able to implement a contingency plan. If in
8 fact you cannot do that, then you cannot state that the
9 site is acceptable.

10 Carrying on on our criteria, item 2 is
11 once we have established that we can predict with some
12 confidence what will happen from contaminant migration
13 from a landfill site and to some extent determine that
14 that prediction is acceptable, then we must develop a
15 monitoring program so that in fact the site can be
16 monitored and to verify our predictions. There is not
17 much point in predicting something and yet not
18 monitoring to see if, in fact, your predictions are
19 met, or we would never know until we had a significant
20 problem at the site whether in fact the site is
21 performing.

22 This is very similar to what I described
23 on our Bayview Park landfill site on the installation
24 of the leachate collection system. The leachate
25 collection system was installed to control surface



1 water discharge or seepage from the site to the surface
2 water, and in fact the monitoring we are undertaking is
3 in fact verifying that what we predicted would happen
4 in fact did.

5 If in fact when the site -- you are
6 monitoring the site and you determine an adverse impact
7 is or will be occurring from the site, you must
8 establish that you have in fact a feasible contingency
9 plan. You have a plan that you can implement and that
10 will mitigate any problems that would occur at the site
11 from a leachate contamination point of view.

12 So, in fact, when we refer to
13 hydrogeologic suitability, we believe that the site
14 must meet these criteria. It must be predictable --
15 the contaminant migration must be predictable and that
16 migration must be determined to be acceptable, you must
17 be able to monitor that migration and, if there is a
18 problem, you must be able to install a feasible
19 contingency system.

20 If you meet all of the above criteria,
21 you would therefore say the site is hydrogeologically
22 suitable.

23 Q. Those three criteria as you have
24 explained them are set out on page 6 and then there is
25 a discussion, as I understand the report, of those

Agreed



1 criteria in a bit more detail on pages 7 to 9, is that
2 correct?

3 A. No. It is essentially the balance
4 of section A which describes that and, in fact, it is a
5 description of items 1 to 5 on page 5, it is more
6 elaboration and it is more explaining how you would go
7 about this, investigations and engineering, and so
8 there is a basic understanding of the procedures for
9 hydrogeological suitability determination.

10 Q. Let me take you to page 7 and I am
11 not expecting you to read it, but if you would
12 highlight it for us when you are addressing this
13 heading of hydrogeologic setting, A.2.0 on pages 7 to
14 9, what is it that you are addressing?

15 A. Well, the hydrogeologic setting,
16 section A.2.0 on page 7, is outlining the procedure of
17 what you are looking for and how you go about
18 determining these sites. We identified that we are
19 looking for in a hydrogeologic setting, a site that
20 minimizes risk to public health and safety, and
21 typically that is sites which are based on low
22 permeability materials with high attenuation
23 characteristics.

24 The Ministry of the Environment has
25 indicated that preference is given to sites that have



1 those characteristics in the natural environment and in
2 fact you are looking for sites that naturally have
3 those characteristics rather than engineering them to
4 that level and the rationale for that is that there has
5 been no long-term performance evaluation of engineered
6 landfill sites. So, their preference is for the
7 natural environment.

8 When you are initially looking for a
9 site you are looking for sites based on low
10 permeability materials with high attenuation
11 characteristics and what is the setting. As we have
12 heard throughout the hearing, the traditional basis is
13 clay and clay till soils and that has moved with time
14 essentially into that basis, and so you would
15 traditionally be looking for sites which would have a
16 thick clay strata as the preferred hydrogeological
17 setting. That is not to say that you would not look at
18 other sites, but as a screening mechanism, you would
19 typically look for a thick clay strata to meet that
20 criteria.

21 Now, to find or use that criterion as
22 the limiting criterion may be somewhat limiting on the
23 basis that there is not that many sites that would meet
24 all of the criteria. I used the example in discussions
25 many times saying that if I had to locate a landfill



1 site using that criterion and solely that criterion,
2 then we would have an awful lot of landfill sites
3 located in the Lambton county area because of the very
4 thick clay tills and lacustrine clays, but in fact not
5 all areas are blessed with that material and so we must
6 look at other sites.

7 When doing that you have to consider
8 that when you are in a glacial environment the clay
9 till could be interbedded with some lenses or pockets
10 of sand and silt and you must determine whether in fact
11 those are continuous and cause any concern. You must
12 install observation wells and boreholes to establish
13 the geological sequence of the site and, from that, we
14 can then determine the migration of contaminants
15 through the geology, primarily in a lateral and to some
16 extent a vertical extent.

17 We also must establish the groundwater
18 quality at the sites prior to doing any landfilling and
19 the rationale for that is that we would want to have a
20 good understanding of the chemistry of the site to
21 assess any changes that may occur from landfilling.

22 Of utmost importance in determining the
23 hydrogeologically setting is the groundwater flow
24 system and from that definition of the groundwater flow
25 system we can then determine the route that



1 contaminants may migrate and from that we would develop
2 what I refer to as our impact assessment.

3 Again, this is written somewhat
4 generically, but it is trying to outline what you are
5 looking for in a hydrogeological setting and
6 essentially it is what we believe what the industry
7 proceeds to do when looking for a landfill site from a
8 hydrogeological perspective.

9 Q. Does that take us over to page 10,
10 the conceptual engineering design portion?

11 A. Yes. On conceptual engineering
12 design, the design is very much based off the
13 hydrogeology and therefore we believe you need a close
14 relationship between the hydrogeologist and the
15 engineer. As I indicated earlier, that is very much
16 an interactive process. The design of the site must be
17 compatible with the hydrogeologic system. It is
18 necessary for the design to minimize the leakage of
19 leachate and to provide for the collection of leachate
20 and in the future, upon closure of the site, to
21 minimize the amount of leachate production.

22 I would like to make one note on dealing
23 with item 3 on page 10. In fact consideration is being
24 given to the fact that rather than limiting leachate
25 production, but to maximize leachate production and



1 therefore the removal of contaminants from the site.

2 If I could give an example, at the Keele
3 Valley landfill site there is a system being installed
4 called a leachate recirculation system, and the purpose
5 of that system is to add water to the site and to in
6 fact leach contaminants from the site and rapidly
7 stabilize the waste. I just want to make a note
8 because typically we look for minimizing it, but in
9 fact at some sites we do not do that for other reasons.

10 If we are in an area where in fact the
11 hydrogeological setting indicates that we have
12 questionable base materials or questionable low
13 permeable base materials then a liner can be considered
14 and in fact the liner is the primary barrier for
15 leachate migration. Typically, clay liners would have
16 a hydraulic conductivity of approximately 10^{-8} .

17 Q. I am over at the top of page 11
18 and I see a reference to clay liners in the first full
19 sentence on page 11:

20 "Clay liners are typically designed to a
21 hydraulic conductivity of 5×10^{-8}
22 cm/sec."

23 A. That was not intended to read as
24 such. What we intended to have there, and perhaps we
25 can correct that, but was to say 10^{-8} as the basis and



1 when we say that, we are talking about the full range
2 of 10^{-8} and that being 1.0 to 9.9×10^{-8} because we are
3 looking at that range and this is the mid-range, but I
4 think it is more appropriate to show the complete
5 range.

6 Q. All right. You are addressing,
7 when you are talking about liners, can you tell me
8 where does that fit in to the objectives, the three-
9 fold objectives back on page 10?

10 A. It deals with item 1, minimize the
11 leakage. If in fact you find that you are not blessed
12 with the hydrogeological setting that allows the
13 natural system to control the leakage, then you are
14 augmenting that natural system by the placing of a
15 liner and the liner is your primary barrier or control
16 of leachate discharging from the site.

17 Q. All right. Going over to page 11
18 you talk about the third objective addressed by the
19 installation of an engineered cover at closure of the
20 site, and looking back at page 10, you are talking
21 about minimizing the amount of leachate production
22 following closure of the facility?

23 A. That is correct.

24 Q. Then you go on page 11 to address
25 certain types of engineering systems that might be



1 installed to achieve that third objective, is that
2 correct?

3 A. Yes, and these are outlining the
4 options available and they entail typically the
5 leachate collection system which would be what we refer
6 to as an underdrain system, a system placed completely
7 under the waste, and it would have a drainage layer
8 being of both permeable soils or stone with a leachate
9 collection pipe and its purpose is the removal of
10 leachate and to control the head of leachate buildup
11 within a site.

12 Q. I direct your attention to the
13 paragraph beginning at the bottom of page 11 where you
14 are addressing the thickness and hydraulic conductivity
15 of the strata underlying the landfill and you note that
16 that is of critical importance. Could you explain why
17 it is of critical importance?

18 A. Well, what lies directly beneath
19 the landfill is in fact in our opinion your primary
20 barrier for leachate migration. The material
21 obviously, and it would be preferable to have a low
22 permeable base, but you must recognize that not in all
23 cases can you have that and so you must look at it, not
24 only as to its permeability but its thickness. What we
25 have outlined here was that you are looking for



1 materials having a permeability of 10^{-7} or 1×10^{-7} as
2 we are indicating, and the industry as a whole is
3 tending to look more at materials of 10^{-8} now, but 10^{-7}
4 is sort of within the bound of what we are looking for,
5 but you are tending to look for 10^{-8} soils.

6 You are also looking in a glacial
7 environment for a thickness in the area of 3 to 5
8 metres, and the reason for that is when you are in a
9 glacial till environment there can be some inclusions
10 of sand and silt lenses and pockets and providing a
11 significant thickness of the till as a whole, you have
12 a much higher comfort level that you have covered your
13 overall bulk permeability of the primary layer being in
14 the order of 10^{-7} and 10^{-8} .

15 Q. All right. Continuing over to
16 page 13, you have a section on impact assessment, and
17 this is addressing one of the criteria you indicated
18 earlier, you want to be able to assess the impact and
19 determine what the effects of failure might be?

20 A. Right. It is necessary for an
21 impact assessment to be able to estimate the estimated
22 time of travel and the anticipated peak concentrations
23 of leachate that may migrate in the groundwater. You
24 must be able to predict that, where it discharges, to
25 the surface water, and what concentrations would reach



1 the site boundary and/or to the receptor of the
2 groundwater. An example would be a well.

3 Q. Then we go to the last two items,
4 pages 14 and 15, the monitoring program you have
5 referred to earlier and you have set a bit more detail
6 out of what the intent of that groundwater monitoring
7 program is at page 14?

8 A. Yes.

9 Q. Firstly we must define the
10 background water quality prior to any landfilling at
11 this site and to assess any change in the site that may
12 happen due to landfilling. We must ensure that any
13 change in the groundwater quality can readily be
14 detected and we must be able to interpret that change
15 with the acceptability criteria.

16 Therefore, in a monitoring program it
17 must be designed to be able to do all of those items.

18 Q. All right. Then, the last item or
19 criteria you have addressed on page 15 is the
20 importance of establishing contingency plans in the
21 event that mitigation of that nature is necessary?

22 A. As I indicated earlier, a
23 contingency plan is a very integral part of the site
24 and should through the monitoring -- should
25 unacceptable environmental impacts occur, you must be



1 able to demonstrate it can be mitigated and there are
2 various means of dealing with that which are outlined
3 on page 15, and those are our hydraulic control or
4 physical containment, and it can go so far as removal
5 of the waste.

6 We are quite familiar with remediation
7 dealing with much of our work on hazardous waste,
8 remediation activities that we do there.

9 Q. This first section sets out the
10 various criteria and minimum standards that go to this
11 definition of hydrogeological suitability you have been
12 referring to?

13 A. That is correct. We have outlined
14 in our opinion what is the criteria you are looking for
15 and subsequently in section C we test each site against
16 this criteria.

17 MR. McQUAID: Mr. Chairman, this would
18 be a convenient time to break.

19 MR. LANCASTER: I think it would be. We
20 will adjourn until a quarter to two.

21

22

23 ---Luncheon Adjournment at 12:26 p.m.

24

25



1 ---Upon resuming at 1:45 p.m.

2 MR. LANCASTER: Please be seated.

3 MR. McQUAID: Q. Mr. Crutcher, we had
4 got to section B in the F report, Exhibit B-617, and
5 that deals with the critique of the technical studies
6 and particularly addresses the Trow Hydrology report.
7 Before we begin our discussion of it I wanted you to
8 explain to the Board, if you would, the relationship or
9 inter-working relationship between you and
10 Mr. Petrie with respect to this part of the report,
11 part C?

12 MR. CRUTCHER: A. As I indicated
13 earlier this morning, I act as the project manager for
14 the work we have undertaken for the City of Burlington
15 and that entailed the hydrogeology and the design and
16 operations as well as the Bayview Park monitoring.

17 The work with regard to the
18 hydrogeology, I work very closely with Mr. Petrie, he
19 is our senior hydrogeologist in the firm, and he was
20 given the task of reviewing all of the reports in great
21 detail and I would interact with John, and we would
22 jointly prepare the report. But, in true essence, John
23 has a better feeling for all the details and the data
24 than do I, given the amount of time he has spent, so we
25 felt it was best for getting into the details on the



1 site, that being in part B under the critique, that
2 John would be better qualified to testify to that than
3 I.

4 Q. Would you hand the baton over to
5 Mr. Petrie, or the microphone.

6 Mr. Petrie, turning to page 16, part B,
7 if I understand the initial portion of the report, you
8 have a summary here of the conclusions that you have
9 reached as a review of the Trow report.

10 MR. PETRIE: A. That is correct and it
11 summarizes the work we did in undertaking the critique
12 of the Trow reports and provides a summary of our
13 conclusions based on that critique.

14 Q. Could you direct us to the
15 appropriate point on pages 16 or 17 where we can pick
16 up your summary?

17 A. Yes. We start initially reviewing
18 the hydrostratigraphy as defined by Trow and it is my
19 understanding that this hydrostratigraphy at the bottom
20 of page 16 was based on the following information, and
21 we have some numbers, No. 1, the inspection of the rock
22 cores, No. 2 is the water levels and vertical hydraulic
23 gradient data, 3 being the single well response tests
24 and the pressure packer tests; 4 being the pumping
25 tests and 5 the computer modeling.

Q. If I understand this section and



1 just to pick up for the Board, subsequently in part B
2 you have examined each of these five sections and have
3 addressed or come to conclusions with respect to
4 whether or not these five sections support the four
5 hydrostratigraphic units that Trow had interpreted?

6 A. Yes, and it is my conclusion that
7 the bedrock at the site cannot be differentiated into
8 the hydrostratigraphic units as proposed by Trow.

9 Q. Do we deal first of all then with
10 the geology -- sorry, with the inspection of the rock
11 cores?

12 A. We do. Based on our inspection of
13 the rock cores, we note the fracture pattern at the
14 site is extremely complex and we have difficulty in
15 defining a degree of connection between those fractures
16 along which the groundwater at the site migrates and we
17 have a significant amount of uncertainty regarding
18 quantifying those hydrogeological parameters that
19 govern the rate and on a local scale the direction of
20 groundwater flow.

21 Q. Continuing this summary portion on
22 page 17 you also looked at the impact on groundwater on
23 the adjacent landfill site?

24 A. Yes. There are two landfill sites
25 situated on either side of the proposed Site F and one

Ans
see
Index





1 being the current Region of Halton landfill, being the
2 Burlington landfill and, secondly, the closed Bayview
3 Park landfill. Based on our assessment of the data
4 generated from those studies, we concluded that it was
5 not possible to demonstrate that the monitoring well
6 screens installed in conjunction with those sites, that
7 those well screens do not necessarily straddle the most
8 permeable fracture zones and, therefore, do not
9 necessarily represent groundwater quality of the major
10 contaminant pathways.

11 Q. You discuss this in more detail
12 later?

13 A. Yes, this is just a summary of the
14 work in part B.

15 Q. Going to page 18, could you
16 indicate to us what conclusions you have reached with
17 respect to the groundwater flow models undertaken,
18 first of all, by Trow?

19 A. Trow provided two groundwater flow
20 models, one included in their initial report and a
21 second, I believe, described as the better fit model
22 which herein we intend to call model B, model A being
23 the initial one in the Trow report. On a review of
24 those two models we conclude that the infiltration rate
25 as determined by the model is very sensitive to changes



1 in the hydraulic conductivity of the shale, and further
2 that a variety of values for the conductivity of the
3 shale can produce a similar pattern of regional
4 groundwater flow.

5 Q. Can you amplify that as I
6 understand we will be discussing it in more detail, but
7 what do you mean by a variety of hydraulic conductivity
8 values producing similar patterns?

9 A. We entered into the computer model
10 in our part C discussion -- in part C of this report we
11 reviewed the Flonet model as provided by Trow and got a
12 copy of that model and ran it on our computing system
13 and we, CRA input a variety of different parameters or
14 different parameters into the model and we were able to
15 reproduce the groundwater flow pattern using more than
16 one set of input parameters.

17 On the basis of that, we concluded that
18 the values for the hydraulic conductivity were not
19 unique as indicated by the model.

20 In part B of this report to which we are
21 now referring, we reviewed the data provided for
22 Trow for their models A and B and showed that they
23 themselves resulted in different values of infiltration
24 into the site using different values for hydraulic
25 conductivity and yet in both cases the regional



1 groundwater flow pattern produced by the model was
2 similar.

3 DR. KINGHAM: When you used the term
4 infiltration you mean water crossing the interface
5 between the landfill and the bedrock as opposed to
6 infiltration at the surface of the landfill?

7 MR. PETRIE: Crossing into the bedrock
8 at the site, yes, and that is in the situation without
9 a landfill and we are addressing the natural
10 infiltration at the site.

11 We concluded on our review that given
12 that the two models provided by Trow using different
13 values of hydraulic conductivity resulting in different
14 values of infiltration does not confirm the
15 hydrostratigraphy of the site as postulated by Trow.
16 We note also that those models provided input data for
17 the contaminant transport modeling undertaken by Mr.
18 Feenstra on behalf of Trow and given that we do not --
19 given that it is apparent to us that the
20 hydrostratigraphy is not confirmed by the model, we
21 also question the transport contaminant modeling
22 undertaken by Mr. Feenstra.

23 Q. All right. Then, you make a
24 comment in the next paragraph on page 18, that the
25 absence of specific review of sections of the Trow



1 report doesn't necessarily imply agreement with the
2 contents and you haven't commented on it directly, I
3 understand.

4 A. That is correct, and surface water
5 comes to mind. We have no discussion on the surface
6 water section as provided by Trow in the CRA document.

7 Q. Then at the bottom of page 18 and
8 on page 19 you have a figure which really summarizes,
9 as I understand it, the various boreholes from the
10 various reports that we have had reference to over the
11 period of evidence?

12 A. That is correct. What I have done
13 for the Board here is make overheads of each of the
14 figures in our report because I find it easier to talk
15 to overheads and, further, if we wish to make some
16 changes we can Xerox the copy of the modified overhead
17 and provide it as an exhibit.

18 The first overhead is an exact copy of
19 Figure B.1.1 from our report which is included at page
20 19 and the page number is in the bottom corner. I
21 should make two comments on this figure, or three.
22 We indicated in the legend running down the left-hand
23 side and when we come to the big star we indicate these
24 boreholes are drilled by Hydrology Consultants in 1986.

25 That is correct, they should not be



1 indicated as PW's as PW to a hydrogeologist implies
2 pumping wells and some of the wells drilled in 1986
3 were pumping wells, they are indicated at PW-1 being on
4 the south property of proposed Site F adjacent to 403,
5 and PW-2 located midway up the site on the western side
6 adjacent to the Burlington site, and PW-3 immediately
7 downgradient of the Bayview site and they are the three
8 pumping wells drilled in 1986.

9 In addition, the Hydrology Consultants'
10 program in 1986 installed some off-site wells, being 14
11 being located below Site F south of the 403, 15 in a
12 similar position but south of the Burlington landfill,
13 and borehole 16 which is shown in the small figure on
14 the right being way down at the shore of Hamilton
15 Harbour.

16 The second thing I wish to point out is
17 that we have a cross-section indicated as running from
18 borehole 4, being an upside down triangle which the
19 legend indicates was drilled by Hydrology Consultants
20 in 1985, to borehole 14 which I just mentioned. The
21 reason for this cross-sectional alignment is that it is
22 provided in Trow's report and it provides -- it is the
23 cross-section upon which they present some geologic
24 data and it is the cross-section on which they align
25 their modeling, so we have chosen to produce our data



1 or data taken straight from the Hydrology Consultants'
2 reports along the same cross-section.

3 I also understand that Gartner Lee
4 drilled some additional wells as part of their
5 monitoring program and we were provided with that
6 information through the hearing, and I don't have it as
7 finalized information, but those boreholes are not
8 indicated on this figure. I believe the numbers are 30
9 and 31 or something like that.

10 DR. KINGHAM: Can I be clear on your
11 first point with reference to the Hydrology Consultant
12 wells of 1986. We understood they were HC wells, but
13 we thought they were pumped as well.

14 MR. PETRIE: Three of them are pumping
15 wells which are PW-1, PW-2 and PW-3. I should not have
16 used this symbol PW which implies all the wells drilled
17 in 1986 were pumping wells. They also drilled 14,
18 being off-site south of the proposed site, 15 south of
19 the Burlington landfill, and 16 located on the shore of
20 Hamilton Harbour, and they are regular observation
21 wells and also drilled during 1986.

22 MR. McQUAID: Q. We really have three
23 PW wells and the other three not.

24 MR. PETRIE: A. The others ideally
25 should have been called HC wells, given that they were



1 drilled by Hydrology Consultants.

2 Q. To go back to the point you were
3 making about the cross-section shown on this figure,
4 page 19 running from 4 through -- is it MB-5 and 14?

5 A. It runs through Hydrology
6 Consultants borehole 4 to borehole 8 and we have not
7 put in the 5 on the cross-section but instead have
8 projected Trow Hydrology Consultants borehole 5 on the
9 cross-section and there is borehole 6 and the reason
10 for the variation is that some sets of data were
11 available at borehole 5 and others at 6 and vice versa.

12 Q. If we look at page 21, do we see
13 the extent of the cross-section shown on page 19?

14 A. We do indeed. The figure on page
15 21, being Figure B.2.1 which I have now put up as an
16 overhead, is taken from Trow's report, being Exhibit H-
17 40. The bottom of the figure indicates that this in
18 the Trow report is indicated as Figure 2 and is page
19 35. We have just Xeroxed the same figure. You will
20 note on the left we have borehole HC4 and moving down
21 slope to the right or to the east borehole 6, borehole
22 8 and borehole 14 at the right of the figure.

23 Q. At this point in section B, just
24 to be sure I understand it, you are looking at the
25 interpretation of the four hydrostratigraphic units,



1 the first section we are now discussing based on
2 inspection of the rock cores or the geology?

3 A. Correct. At this point we are
4 really looking at the four geological areas postulated
5 by Trow.

6 Q. All right.

7 A. They have four geological areas
8 and then based on their information obtained by
9 hydraulic tests and water levels, et cetera, they
10 defined four hydrogeological areas. At this point we
11 are addressing just the four geological areas.

12 Q. Going back to page 20 and picking
13 up the text, you begin by indicating that CRA does not
14 agree, and this is under B.2.2, the bedrock fracture
15 patterns, and CRA does not agree with the delineation
16 of the fracture zones as interpreted from a detailed
17 study of the core logs. This delineation as presented
18 by Trow, and that is the page we were looking at, page
19 21, and could you explain to us why you do not agree
20 with that delineation?

21 A. I will take you through the steps
22 by which we evaluated this. In order to investigate
23 the fracture frequency profile at this site, we started
24 from the borehole records provided by Trow and those
25 borehole records are contained in Exhibit 40A, the

1 appendices to the Site F report, and they are detailed
2 in Appendix 2.

3 In any one of the core logs which show
4 the rotary drilling of the bedrock as undertaken by
5 Trow, there is a column marked column 14 in the
6 appendices headed up fracture frequency. We went to
7 those fracture frequency profiles in order to evaluate
8 the fracture frequency pattern encountered at the site
9 and as reported by Trow.

10 In order to transpose this data taken
11 from Appendix 2 of Exhibit 40A, the fracture frequency
12 profiles, on to the geologic cross-section prepared by
13 Trow, we ourselves prepared this cross-section.

14 Q. This is found at page 23?

15 A. Correct. Figure B.2.2 which I now
16 have on the overhead. You will note that this cross-
17 section starts at borehole 14 on the northwest or left-
18 hand end and passes through borehole 6, borehole 8 to
19 borehole 14. Now, the background data on this figure,
20 being the geological areas, the upper one being the
21 moderately weathered and fractured shale and then the
22 weakly fractured massive shale, the highly fractured
23 shale and then the moderately fractured shale, and
24 those words come from the Trow report and were provided
25 previously on Figure 21.



1 We have just taken the figure that was
2 B.2.1 on page 21 and redrawn it ourselves and I have
3 stretched the scale a bit from left to right for ease
4 of the presentation of the data. It is the same cross-
5 section presented previously on page 21.

6 The new information we have put on this
7 figure is indicated in the legend where we have the
8 borehole marked by a vertical line and the well screen
9 marked by a rectangular box with a few lateral lines
10 indicated as well screens. To the left of that we have
11 a number in brackets. The boreholes at this site have
12 been numbered as HC4-1, -2, -3 or -4 and -1, -2, -3 or
13 -4 is the number of the well screen installed at
14 various depths within that borehole, in this case being
15 HC4.

16 We have also indicated to the left of
17 the borehole a number, looking at a legend at the top
18 of the figure being 7.5 metres as indicated to the
19 right of the borehole, and that is the depth, BGS being
20 below ground surface. The black data, if I can
21 describe it thus you see adjacent to each borehole log
22 is indicated in the top right-hand corner of the figure
23 in the legend headed fracture frequency.

24 This is taken directly from the fracture
25 frequency profiles obtained from Trow's Appendix 2 in



1 their Exhibit H-40A and is marked as column 14 in their
2 coring records. Adjacent to that legend we have a
3 series of numbers here and again that information is
4 taken directly from Trow and I would like to refer to
5 the beginning of Appendix 2 of Exhibit H40-A.

6 There is what is described as
7 explanatory sheet to core logs and as you look down the
8 right-hand side of that sheet, being the explanatory
9 sheet to core logs, there are columns 13, and if you
10 move down further to 14, I will read it to you. It
11 says "Fracture frequency - number of natural joints
12 occurring over a metre length of core. All natural
13 joints are counted irrespective of the number of joint
14 sets." And then there is a little block diagram, if
15 that is the correct way to describe it, being the
16 fracture frequency.

17 I wish to point out a couple of
18 corrections which I believe were pointed out during the
19 course of Trow's evidence in chief. The first column
20 should read "less than 0.3/m" which means there is less
21 than .3 of a fracture per metre, or ideally perhaps one
22 fracture per 3 metre length of core. That would be
23 indicated if it were encountered by a blank set of
24 blank, if that's the right word, on the bar graph.

25 The next column down being one coloured-



1 in portion of the bar graph, which is 0.3 to 1 which is
2 a number of fractures per metre length of core.
3 Invariably as you run down you get 1 to 3 fractures per
4 metre length of core and the next one being 3 to 20
5 fractures per metre length of core, and the last one
6 being where all the bar graphs are coloured in so it is
7 completely black from left to right, being greater than
8 20 fracture per metre length of core.

9 Q. We have taken the information from
10 column 14 and transposed it directly on to the cross-
11 sections as you see it. We have underneath each set of
12 bar graphs put the scale on for convenience. As I look
13 at borehole 4, being the one on the left-hand of Figure
14 B.2.2, I see that we have greater than 20 fracture per
15 metre length at the point where the black lines extend
16 across to the far right edge of that domain. We have a
17 significant set at about 10.5 metres below ground, and
18 I am reading 10.5 metres below ground from the left-
19 hand side of the borehole log.

20 We have another set at about 12.5 metres
21 below ground, another set at 15 metres below ground,
22 another set at 17 metres below ground, and between
23 about 19 and 22 we have a set where the fracturing is
24 significantly less, and in that case it is less than 3,
25 being the number at the bottom of the column, 3



1 fractures per metre length of core, and then we come
2 down to 23.5 metres of depth where we have a
3 significant amount of fracturing, again at 25, 26-1/2,
4 28-1/2. I have just highlighted a few and there are
5 other points there.

6 I would like to point out one thing from
7 this figure. Reading from the third paragraph on page
8 22, second sentence...

9 Q. Just one moment.

10 A. I beg your pardon.

11 Q. The third paragraph on page 22.

12 A. Yes, the second sentence, reads:

13 "Thin zones of as little as 5 cm in
14 width are identified on these logs."

15 These logs being the coring record, column 14, obtained
16 from Trow's Appendix 2. They are indicated by the unit
17 width line, the very thin line. I interpret that to
18 indicate that where fracture zones as thin as 5
19 centimetres have been encountered, the geologists
20 logging the core which he withdrew from the borehole
21 could define thin zones of fracturing or more
22 extensively fractured rock. I believe these fracture
23 profiles provide a good indication of the fracture
24 frequency within the vertical profile at any one
25 borehole.



1 To examine that in a little more detail,
2 I went to the Trow laboratory to review the logs and
3 now we are looking at page 24, the first complete
4 paragraph. I looked at the core from HC4 and that same
5 core was presented to the Board as an exhibit, but I
6 don't recall which number, during the course of the
7 hearing.

8 It is apparent from the core that the
9 description provided by Trow matches reasonably my
10 examination of the core. I say reasonably, because the
11 core was old before I looked at it and it is recognized
12 the core may have additional breaks or have moved a
13 little bit in the boxes. I am in agreement with the
14 core log data as I can read it and as provided by Trow.

15 When we look at the profile developed at
16 any one borehole, and I can start with HC4 again, we do
17 see there are pronounced differences in the fracture
18 frequency profile with depth and highly fractured zones
19 are encountered as I described earlier. We also have
20 some weakly fractured zones encountered at depths of
21 about 9 metres, again at about 11 metres and the sixth
22 zone I indicated earlier was about 18 to 20-odd metres
23 below ground, and again we find weakly fractured rock
24 at depths of about 25 and again at about 29-1/2 metres.

25 It is my reading from this fracture



1 profile that one can encounter highly fractured rock in
2 Trow's unit 2, and this is geologic unit 2, and I wish
3 to stress the distribution of the rock units and the
4 hydrogeologic units is not exactly the same. Within
5 geologic unit 2, being the moderately fractured and
6 weathered shale, we have highly fractured rock at some
7 locations and we also have highly fractured rock in the
8 highly fractured unit at some locations.

9 We have weakly fractured rock, and I am
10 using weakly fractured rock as a relative term given
11 the scale of fracturing I see in these borehole coring
12 records, but weakly fractured rock being as much as
13 three fractures per metre length of core. I see weakly
14 fractured rock in geologic unit 2 being the moderately
15 fractured shale and I see it in the weakly fractured
16 shale being geologic unit 3 and again I see it in the
17 highly fractured shale being geologic unit 4.

18 Within the vertical profile I see a
19 complex picture of fracture patterns. I do not see a
20 simple delineation between the four geologic zones of
21 the rock as defined by Trow.

22 The second thing I would look at would
23 in the coring record is the correlation between any one
24 borehole and the next, or indeed any boreholes across
25 the site. To illustrate this we can look at HC4 and

yes
X



1 HC6. Looking at the highly fractured zones we have
2 encountered at various depths within the geologic rock
3 unit 2, the question I have in my mind is regarding the
4 correlating of this fracture from one borehole set to
5 the next and which of these highly fractured rock units
6 or segments of rock, I should describe, should line up
7 with the highly fractured segments I encounter over
8 here at HC6?

9 I ask the same question again with
10 respect to the weakly fractured rock, being that rock
11 which has a fracture frequency of three fractures or
12 less per metre length and the identified zone up here,
13 and up here being in the moderately fractured shale,
14 doesn't line up or correlate to the weakly fractured
15 zones identified in borehole 6. We can go through the
16 same exercise at HC6 to HC8 and again from HC8 to HC14.

17 In each case the question I come up
18 with, I am not comfortable correlating any one fracture
19 zone, discrete fracture zone or highly fractured zone
20 or discrete weakly fractured zone with its counterpart
21 in any of the adjacent boreholes. I would not
22 correlate the fracture pattern from one borehole to the
23 next.

24 To that end I conclude that based on the
25 fracture pattern I cannot correlate and define the zone

X
yes
- confirm
Ours
X
with
H220



1 as Trow have defined it here.

2 One thing I do notice in examining these
3 core logs, and indeed the other ones we examined, was
4 that the fracture frequency shows a tendency as
5 illustrated at HC14 to a decreasing number of fractures
6 with depth. However, that tendency is not very well
7 defined and shows some inconsistencies of which HC4
8 provides a measure. We have generally intermittent
9 highly fractured zones in the top 25 -- 18 metres or
10 so and then we have a pronounced weakly fractured shale
11 consistent with Trow's definition of weakly fractured
12 rock.

13 MR. HODGSON: I would like the record to
14 indicate where on that borehole the witness is agreeing
15 and at what elevation we encounter the weakly fractured
16 shale.

17 MR. PETRIE: I am saying weakly
18 fractured shale.

19 MR. HODGSON: You are pointing, and I
20 don't mean to criticize the witness, but I want the
21 record to be clear as to where he is pointing when he
22 is describing it and I am happy to have his evidence,
23 but I would like to be able to examine on it later.

24 MR. PETRIE: The depth at approximately
25 18 metres to about 20-odd metres where we have a zone



1 of less than 3 fractures per metre length at the
2 elevation described by Trow as weakly fractured shale,
3 being geologic unit No. 3. Now, lower down in the
4 borehole there is an increase in the incidence of
5 fracturing at the elevations described by Trow as
6 highly fractured shale.

7 The point I was making is that while in
8 some boreholes we have a tendency to a decrease in
9 fracture frequency with depth, it is not consistent
10 across the domain of this cross-section.

11 MR. McQUAID: Q. Picking up in the
12 text, if we go over to page 25 does that summarize the
13 conclusions you reached with respect -- I am referring
14 to the first full paragraph and the second paragraph on
15 page 25?

16 A. It does. We conclude that based
17 on the variations in the fracture patterns, these
18 geologic units cannot be delineated from an inspection
19 of the core samples. The core samples do show the
20 existence of discrete fractured zones, often less than
21 20 centimetres thick, which are bounded by a less
22 fractured rock mass. There is a significant variation
23 in the frequency of fracturing within this less
24 fractured rock mass with some lengths of core showing
25 fewer than 3 fractures per metre length.



1 I conclude in the last paragraph on page
2 25, that CRA does not consider it possible to correlate
3 the fracture pattern between the boreholes and
4 therefore cannot differentiate the site into distinct
5 geologic units each with its own characteristic
6 fracture pattern.

7 Q. Turning -- again we are looking at
8 the Trow interpretation of the four hydrostratigraphic
9 units, and over at page 26 you were looking, as I
10 understand it now, at again data presented by Trow,
11 water levels, hydraulic gradients, hydraulic
12 conductivity, pumping tests and tritium distribution?

13 A. Yes, we examined each of those
14 points you mentioned, being the water levels, hydraulic
15 gradients, hydraulic conductivity, pumping tests and
16 the tritium distribution in order to assess for
17 ourselves whether the hydrostratigraphic units as
18 postulated by Trow can be supported by the set of data.

19 I say hydrostratigraphic, as we are now
20 dealing with the hydraulic properties of the rock and
21 they have different distribution as compared to the
22 geologic rock units presented on the figure I have just
23 taken down.

24 By way of introduction, I have just
25 obtained Exhibit B-516 taken from Trow's report, and it



1 was Figure 4 in Trow's report, Trow's report being
2 Exhibit H40. This provides the summary of the
3 hydrostratigraphic units encountered.

4 Q. You are looking at B-516?

5 A. B-516.

6 Q. You have at page 27 a similar
7 summary and this is actually a photostat from page 49
8 of the Trow Exhibit, H40?

9 A. That is correct.

10 Q. The difference we have on B-516,
11 and I have forgotten which of the witnesses but
12 somebody actually ...

13 A. I am not referring to the blue
14 line indicated on B-516, my intention is to provide the
15 figure as taken from Trow as I walk through the
16 hydrogeologic data.

17 Q. I recall it was Dr. Rowe who
18 delineated on B-516 the approximate area of the
19 landfill site itself?

20 A. It may have been Dr. Charlesworth.

21 Q. One or the other.

22 A. Quite right. On the overhead ...

23 MR. HODGSON: I am sorry, but I think --
24 my recollection of the evidence is that that is
25 Dr. Rowe's modelled segment, and in fact it is



1 downgradient from the landfill.

2 DR. KINGHAM: Our recollection is that
3 the landfill extends up to the 1A zone at the top.

4 MR. PETRIE: I will make no reference to
5 the blue line on B-516. My reason for putting it up is
6 that I am going through a sequence of figures ...

7 MR. LANCASTER: You won't go offside
8 then.

9 MR. PETRIE: Before you I have Figure
10 B.3.1 which is taken from page 27 of our report and I
11 wish to make a couple of notes here. This figure, as I
12 indicated was taken from Trow, Figure 4, page 49, that
13 being the figure I have behind me indicated as B-516
14 and, secondly, we have made some additional notations
15 on the top of this cross-section where we have
16 indicated where we believe HC4, HC6, HC8 and HC14 are
17 located relative to this cross-section.

18 This is a schematic cross-section
19 summarizing the hydrostratigraphy of the site and we
20 have for our own information provided where we believe
21 the approximate borehole locations are and it was not
22 intended to be the definitive location on these
23 boreholes and I don't believe Trow implied this figure
24 was definitive with respect to any one borehole
25 location.

Look at
X



1 This figure then describes the
2 hydrostratigraphic units as defined by Trow in summary
3 form. Unit 1 I am indicating in the legend at the
4 bottom is where we have 1(a) being the till unit, a
5 wedge at the top or left-hand side of the site and 1(b)
6 indicated as the discharge zone till and that is
7 located downgradient -- at the downgradient limit of
8 the site extending to Highway 403.

9 Of the bedrock rock units we have, we
10 have hydrogeologic units 2, 3, 4 and 5, 2 being the
11 fractured shale unit which is highly weathered at the
12 surface, and that is the uppermost fractured rock unit,
13 3 being the weakly fractured massive shale, 4 being the
14 wedge, if I can describe it thus, of highly fractured
15 rock underlying the downgradient limit or extent of the
16 site, and this would be indicated on cross-sections
17 within HC4, HC6, HC8 and, we suspect, HC14.

18 Hydrogeologic unit 5, the moderately
19 fractured bulk shale unit, is the massive segment of
20 rock which underlies the base of this sequence defined
21 by Trow. I wish to point out on the figure we have the
22 hydraulic conductivity values assigned by Trow to each
23 of these rock units and the till being 10^{-7} , and I am
24 referring to the hydrogeologic unit 1(a), rock unit 2
25 with a permeability of 10^{-5} centimetres per second,



1 rock unit 3 being 1×10^{-7} centimetres per second, rock
2 unit 4 is assigned at 1×10^{-2} centimetres per second.

3 There has been a lot of discussion
4 addressing that value in the report and in chief by
5 Trow, and I believe that 1×10^{-3} is an appropriate
6 number as defined by Mr. Sobanski. Rock unit 5, being
7 the base of the sequence, having a permeability of $1 \times$
8 10^{-6} .

9 DR. KINGHAM: For the record you have
10 not changed any of the values on this original Figure 4
11 from Exhibit H-40? You have just added the well
12 locations.

13 MR. PETRIE: That is correct and we have
14 added our interpretation of the well locations and
15 indicated the source for this figure being Trow and
16 labelled it our Figure B.3.1

17 MR. McQUAID: Q. To backtrack, you
18 made a comment about unit 4 being 10^{-3} and I wasn't
19 sure I actually heard what it was you said?

20 A. It is my understanding that 10^{-3}
21 was the value modelled by Trow in their model A, the
22 first model documented in H-40. This value came about
23 from a determination of pumping tests which I
24 understand, 10^{-3} is now considered as a more
25 appropriate number.



1 Q. You will be commenting on your
2 views with respect to these conductivities later?

3 A. Most definitely. I provided the
4 figure at this point in time just to provide a summary
5 of the schematic hydrogeology provided by Trow and this
6 is the hydrogeologic sequence defined by Trow to which
7 I am addressing my comments.

8 Q. You make the point on page 28
9 which I think we recall that the defined geologic units
10 and the ultimate hydrogeologic units are not
11 necessarily equivalent as Mr. Beechinor explained to us
12 during his evidence?

13 A. Yes. We have on page 29, the
14 following page, a copy of an exhibit provided by Trow
15 during the course of cross-examination. It is our
16 Figure B.3.2, Exhibit H-220, and it was described, I
17 believe, as the hydrostratigraphic framework working
18 drawing.

19 At this point in time it was apparent to
20 us that the hydrostratigraphic units, and I am
21 referencing B-516, these hydrostratigraphic units
22 listed as 1 to 5 were not the same as the geologic
23 units I previously indicated as Figure B.2.1 on page 20
24 of this report -- page 21. We were under some
25 misunderstanding that the geologic units and the



1 hydrogeologic units had the same definition and space,
2 but that is not the case.

3 Q. You reached that conclusion on
4 reading the report before you heard the evidence, is
5 that correct?

6 A. No. On our reading of the report
7 we had not understood from it that the geologic units
8 were not coincidental with the hydrogeologic units. It
9 was not until Exhibit 220 was provided, and I believe
10 that that was in cross-examination, that it became
11 apparent to us that the geologic units and the
12 hydrogeologic units, although named with similar names,
13 were not the same rock units or defined in space in the
14 same way.

15 Q. Could you relate if you would H-
16 220, the hydrostratigraphic framework and the summary
17 of the hydrostratigraphic units we see back at page 27?

18 A. Mr. Beechinor and Mr. Sobanski in
19 reviewing Exhibit H-220 provided to the Board the
20 elevations at which hydrogeologic units 3 and 4 and 2
21 intersected at various boreholes. We took that
22 information and plotted it in cross-section on B.3.3
23 which is on page 30 of the report. It is the same
24 figure I have on the overhead now.

25 We have the same cross-section alignment

Look
X



1 I showed previously going from borehole HC4 at the
2 left-hand side and going down the slope through HC6,
3 HC8, and HC14. We have the same borehole locations and
4 screen elevations, et cetera, as indicated before. We
5 now have, as indicated in the legend by the sloping
6 writing, we have, for instance, the moderately
7 fractured shale and that is a hydrogeologic unit and
8 the brackets we have behind the indication of that unit
9 on the cross-section refers to the number of the unit
10 and in this case I am looking at the moderately
11 fractured and weathered shale which has a small (2)
12 behind it and that is hydrogeologic unit No. 2.

13 We have the weakly fractured massive
14 shale being hydrogeologic unit 3 and underlying the
15 sequence -- I beg your pardon -- the highly fractured
16 shale, hydrogeologic unit 4 near the bottom, and the
17 base of the sequence is the moderately fractured shale
18 which is described as hydrogeologic unit 5. At the
19 bottom of the figure I have indicated the source for
20 these various pieces of information and one is the
21 borehole locations and screen elevations which come
22 from the appendix to the Site F report, being Exhibit
23 H-40A; the hydrostratigraphic units, units 2, 3, 4 and
24 5 as I have just indicated being from Exhibit 220, the
25 previous figure in our report which was located at page



1 29. On this figure I have also shown one of the
2 geologic units as indicated by Trow and in the legend
3 we have a stippled area being geologic unit -- it is
4 the highly fractured shale and I have indicated the
5 highly fractured shale in cross-section with this
6 stippled area.

7 Q. What does it show you when you put
8 that geologic unit on top of the hydrostratigraphic
9 units?

10 A. It indicates that the geologic
11 units and the hydrogeologic units are not necessarily
12 coincident at all and at borehole HC6, for example, we
13 have the geologic highly fractured shale encompassed
14 within the domain of the hydrogeologic weakly fractured
15 shale, unit 3, and indeed at borehole HC6, the geologic
16 highly fractured shale does not lie within the domain
17 of the hydraulic or hydrogeologic highly fractured
18 shale, being unit 4.

19 Mr. Beechinor and Mr. Sobanski pointed
20 this out in cross-examination in which they indicated
21 it was not appropriate just to take the fracture
22 patterns or the discontinuity pattern which I believe
23 was Mr. Beechinor's words, and it was not appropriate
24 to take that pattern to define the hydrogeologic units
25 at this site, and my review of that figure indicates

oh
X



1 just that. It is not appropriate to take the fracture
2 distribution as delineated in any one borehole and
3 interpret from that the hydrogeologic characteristics
4 of the rock mass.

5 Q. Perhaps in summary you could give
6 it to us, but having looked at this first component,
7 and superimposing the hydrostratigraphy, H-220 and so
8 on, what is this leading you to in terms of an opinion
9 or conclusion?

10 A. That the geologic pattern as
11 defined by the fractures encountered in any one
12 borehole does not define the hydrogeologic pattern or
13 sequence of rock strata at the site. To that end we
14 believe Exhibit H-220 in itself, and I should point out
15 on H-220 there is a variety of technical information
16 and one set of which is the fracture patterns; and
17 taking the fracture pattern data from H-220, it does
18 not allow you to define conclusively the hydrogeologic
19 sequence of strata at this site.

20 Q. All right. Do we know turn to
21 page 31 in your discussion at B.3.2 of water levels?

22 A. Yes. We looked at the water level
23 data provided by Trow in an attempt to see if that
24 hydraulic information would allow one to interpret the
25 existence of the hydrogeologic units as postulated by



1 Trow. On page 32 we provide the set of water level
2 data and I have that as Figure B.3.4 and I have put it
3 on an overhead here, and I wish to put up a second
4 exhibit here.

5 Q. Just before you cover B-516,
6 perhaps I should ask you to comment on page 31 to one
7 other observation you seem to be making in your text
8 and I am not sure you have testified to it. I am going
9 to the second paragraph on page 31 where you make the
10 observation:

11 "From an inspection of Figure B.3.2
12 (Exhibit H-220) a thickness for the
13 weakly fractured shale... is not
14 supported."

15 Do we find that on B-516 also?

16 A. That is correct.

17 Q. Nor is the wedge shape for unit 4
18 supported by the field data?

19 A. Can I take those one at a time?
20 The weakly fractured shale, being hydrogeological unit
21 3, has a thickness, and I am referring to B-516, it has
22 a thickness of 20 metres as indicated on the left-hand
23 side of the figure. When we go through an inspection
24 of Exhibit H-220 we find that that zone as interpreted
25 or as provided by CRA on Figure B.3. -- Figure B.3.3.



1 I had better put that up again as I think I got ahead
2 of myself.

3 I have returned to B.3.3 being the
4 hydrostratigraphic units as interpreted from Exhibit
5 H-220, and you will notice that hydrogeologic unit 3 is
6 indicated on Exhibit B-516 as being a layer of a
7 thickness of 20 metres extending across much of the
8 site, although the very far downslope portion, that
9 unit thins. When we look at B.3.3, we find that the
10 hydrogeologic unit 3 is 15 metres thick at HC-4 and
11 indeed it does thin across to HC6 and HC8. However, we
12 do not see it as having a thickness of 20 metres at
13 this portion of the site.

14 DR. KINGHAM: I want to make sure I
15 understand that. The geologic unit 3 is 15 metres at
16 HC4 and thins across the site, and the
17 hydrostratigraphic unit 4, I guess ...

18 MR. PETRIE: Could I start again? I
19 think I have misindicated that to you.

20 Hydrogeologic or hydrostratigraphic are
21 synonymous and the word hydro is the key word here. In
22 the hydrostratigraphic units as indicated on B-516, we
23 have hydrostratigraphic unit 3 having a thickness of 20
24 metres. When we refer to the working drawing provided
25 by Trow, that being H-220, provided in CRA's report at



1 page 29, we do not find a thickness of this zone of 20
2 metres. The thicknesses that we find I have indicated
3 in Figure B.3.3 on the overhead before you. I find the
4 hydrogeologic zone at borehole HC4, for example, is 15
5 metres in thickness and thinning to, it looks like,
6 less than 10 at HC6.

7 We indeed see a thinning of the unit at
8 the downgradient slope as indicated on B-516, but we do
9 not see a uniform thickness of 20 metres under this
10 site.

11 Similarly, when we review Exhibit H-220
12 we do not get a clear indication of the wedge shape of
13 hydrogeologic unit 4. In Exhibit B-516, hydrogeologic
14 unit 4 has a pronounced wedge and at the middle of the
15 site it pinches out to zero thickness and in taking the
16 data from H-220, we find that the highly fractured
17 shale, and I am referring to B.3.3, is less than 10
18 metres and so it is uniformly 7 to 8 to 9 metres from
19 HC4 across to HC14 as defined by Trow.

20 I do not see a wedge shape for that
21 highly fractured shale as it is indicated on Exhibit B-
22 516.

23 DR. KINGHAM: Are we to understand from
24 B.3.3 that from a geological perspective the highly
25 fractured shale is something of the order of 6 or 7



1 metres thinning to 3 or 4 metres and then broadening
2 again south of HC6?

3 MR. PETRIE: That is one point you are
4 to understand from this.

5 DR. KINGHAM: Thank you.

6 MR. MCQUAID: Q. I am sorry, Mr.
7 Petrie, I should have taken you through that before.
8 So, can we then go to the water level portion of the
9 report at page 31. You have put up this figure on page
10 32, the overhead for it, and I wonder if you could
11 explain how you came to draw it and what the
12 significance is of these lines, the profile lines or
13 equipotential contour lines is what I think they are
14 described as?

15 MR. PETRIE: A. Could I draw the
16 Board's attention to a new exhibit first? I have
17 behind me a figure entitled "Hydrostratigraphy - Site F
18 Hydrogeology" and this is the base cross-section which
19 I am using on all the cross-sections I am speaking to
20 and it shows the hydrogeologic units as proposed by
21 Trow, it shows the well screens being boreholes HC4,
22 HC6, HC8 and HC14. It is on this cross-section we have
23 superimposed in the previous case some geologic data
24 and in this case we have superimposed water level data.

25 Q. We don't see that base drawing in



1 your report?

2 A. No. This base drawing unedited or
3 without any additional data is not provided in the
4 report.

5 MR. McQUAID: I guess we should mark
6 that.

7 MR. LANCASTER: That is Exhibit B-620.

8 ---EXHIBIT NO. B-660: Superimposed water level data

9 MR. PETRIE: I have provided Exhibit
10 B-620 so you can see where we have added to the base
11 cross-section. I am referring to B.3.4 and as
12 indicated in the legend we have in brackets the water
13 elevation in metres above sea level. This data is
14 taken -- at the bottom we have a source as (3), the
15 water elevations of April of 1986 and they are provided
16 in the Trow report, being Appendix 5 of H-40A.

17 We have taken the available water level
18 data and for the appropriate water well screen or
19 piezometer we have bracketed the elevation as measured
20 at that point.

21 MR. McQUAID: Q. Let me go through.
22 There is a source in the legend and I wanted to pick
23 them up in order. Your source 1 and 2 are both Trow's
24 exhibits respectively H-40A and H-220?

25 MR. PETRIE: A. They are the same



1 source as we see referred to on B-620 which I have as
2 the exhibit behind me.

3 Q. Picking those up in the legend you
4 have the borehole numbers, the piezometric surfaces and
5 then the water elevation, the well screen and the
6 number. That basically would be the first entries you
7 would get on the legend from those two sources, is that
8 correct?

9 A. That is correct and the number on
10 the left being the number of the well screen and the
11 value on the right being the measurement of the
12 piezometric elevation at that point as reported by
13 Trow.

14 Q. Then the water elevations are from
15 Appendix 5 in H-40A?

16 A. That is correct, as indicated at
17 the bottom, the source and footnote 3.

18 DR. KINGHAM: Would you tell us how you
19 decide to orient those equipotential lines between well
20 holes. We understand how you locate them between
21 piezometers at a given well hole, but if you look at
22 the 110, 115, 120 lines between HC6, HC8 and HC14 where
23 they emerge at the ground surface, how do you decide
24 those are shooting up as they do?

25 MR. PETRIE: The position of the



1 contours being the equipotential contours being
2 indicated by the solid lines is my interpretation or my
3 contour of the piezometric data indicated in brackets.
4 I would like to point out that the piezometric data
5 indicated within a bracket at any one point is the
6 piezometric elevation or pressure of the water as
7 measured at an isolated screen.

8 I am pointing at HC8 and piezometer 2
9 and adjacent to it we see the number 115.59. At that
10 restricted interval, being the domain of that small
11 square which is a representation of the piezometer
12 screen, that is the pressure head measured at exactly
13 that point.

14 So, we have some fixed points on this
15 figure which I have used to assist me in contouring and
16 each point is related to each well screen. There is
17 another line on there which provides me with some
18 information for this contouring procedure and that is
19 the dashed line I have drawn along the top. This is an
20 interpreted dashed line which as indicated on the
21 legend indicates the position of the water table.

22 At each well we have a precise
23 measurement of the elevation of the water table and now
24 I am referring to HC4, piezometer 4, and it has an
25 elevation of 135.44. We come down to HC6 and it has an



1 elevation of 126.88. Between those two points it is my
2 interpretation that the water table contour will
3 approximate the shape of the ground surface, so I have
4 drawn that dashed line between those two points and I
5 have extended that dashed line and joining it down to
6 the water table, as I understand it, at HC8 and again
7 for HC14.

8 MR. McQUAID: Q. Can you be specific
9 and concentrate for Dr. Kingham's question on the
10 equipotential contour line of 130?

11 MR. PETRIE: A. I have another point
12 which I have yet to bring out.

13 Q. Okay.

14 A. Where the water table elevation --
15 can I start again? The equipotential contour and the
16 water table elevation are coincident where they
17 intersect. For instance, for the elevation of the
18 equipotential contour being 130 and to which I am
19 pointing, where we have the elevation of the water
20 table at 130, that is a point which lies on the
21 equipotential contour of 130.

22 In describing the contour 130 or 130
23 metres in elevation above sea level, I have one fixed
24 point on the water table and I have interpolated
25 points between water well screens. If you only took



1 those points you might be tempted to draw a straight
2 line across there. I have attempted to provide some
3 shape to these contours by referencing the hydrogeology
4 as indicated in the background of Trow's layers.

5 For instance, the weakly fractured
6 massive shale, being unit 3, that is indicated by Trow
7 as being the tightest hydrogeologic unit at the site.
8 A tight layer is essentially low permeability and in
9 low permeable zones we often find the direction of
10 groundwater flow tends to be in the vertical or
11 dominated by vertical flow, either up or down,
12 depending on the relative pressures or water level
13 elevations in the units above or below.

14 In this case, we find below the weakly
15 fractured shale we have highly fractured shale, unit 4,
16 and at borehole HC4, piezometer 1, we find a water
17 level elevation of 122.96.

18 Now, it is my interpretation or obvious
19 interpretation that water is flowing in the vertical
20 plane, it is flowing downward as opposed to upward and
21 I am only referencing the vertical plane at that point.

22 Given that this interpretation is
23 provided by Trow, I have attempted to reproduce the
24 contours I would expect in a flow regime, for example,
25 at rock unit 3 dominated by vertical downward flow.



1 For highly fractured shale, being rock unit 4, I would
2 expect to see lateral flow dominate so that the water
3 draining down through hydrogeologic unit 3 would move
4 down in the vertical plane and then move -- we can
5 simplify it -- at right angles or laterally off-site in
6 this direction.

7 To that end I would expect to find
8 contours distributed vertically across this unit. I
9 tried to do that at places, for example, east or
10 downgradient from HC8. I tried to keep the hydraulic
11 gradient or -- sorry, the piezometric contour quite
12 steep, a steep piezometric contour or a vertical
13 piezometric contour which indicates horizontal flow and
14 a horizontal piezometric contour indicates vertical
15 flow.

16 So, I have introduced a bias in the
17 manner in which I contoured this data to reflect the
18 hydraulic conductivity of each of the hydrogeologic
19 units as proposed by Trow.

20 What I would have expected to see in
21 this figure is that we would have had horizontal flow
22 through the highly fractured shale if we had 8 metres,
23 and I am estimating the thickness between those lines,
24 but if we had 8 metres of highly fractured, in essence,
25 highly permeable rock at that location. I also would



1 have expected to see a component of upward flow to here
2 and given that the highly fractured shale as proposed
3 by Trow has a permeability of 10^{-3} , and that is
4 centimetres per second, when the moderately fractured
5 shale beneath as a permeability, I believe, of 10^{-6}
6 centimetres per second.

7 Given that the highly fractured shale is
8 the most permeable of the defined units defined by Trow
9 at the site, I would have expected a component of
10 upward flow to converge on this side. My
11 interpretation of the contours is that I do not see
12 upward flow to converge on this highly fractured shale,
13 but I do, however, see downward flow toward this point
14 but I notice that it continues in a manner in which I
15 have contoured it essentially through the highly
16 fractured shale.

17 An additional point to make is that I
18 have contoured the upper zone of more vertical contours
19 which indicate there is a component of lateral flow
20 through here and again consistent with the hydraulic
21 conductivity contrasts as presented by Trow. That is a
22 broad...

23 MR. HODGSON: I am sorry, but "a
24 component of lateral flow through here" and I think it
25 will be convenient if we had a red marked example of



1 where "through here" is for the record.

2 MR. PETRIE: Should I draw the flow
3 arrow or the domain of the zone?

4 MR. HODGSON: It is your evidence so
5 draw the line wherever you want.

6 MR. PETRIE: I will note in the legend
7 here G/W being groundwater flow direction.

8 MR. LANCASTER: We had better mark that.

9 MR. McQUAID: We had better mark that
10 separately. This is the overhead at page 32 on which
11 you have made the red marking for the groundwater flow
12 direction.

13 MR. LANCASTER: B-621.

14 ---EXHIBIT NO.B-621: Copy of Figure B3.4 with
15 groundwater flow direction

16 MR. PETRIE: This figure then provides a
17 regional or large scale picture of the pattern of
18 groundwater flow at this site, at least within the
19 domain of this cross-section.

20 DR. KINGHAM: I would like to make sure
21 I understand this figure. Are you telling us that the
22 piezometric measurement from which you derive your
23 equipotential lines along with other information don't
24 correspond to the equipotential lines you would think
25 should exist if the geological structure was what you
thought it should be?



1 If you look, for example, at your line
2 120, the equipotential line, you told us a minute ago
3 that you thought the groundwater, if that was from
4 moderately fractured shale to highly fractured shale,
5 that the groundwater flow would be up to the highly
6 fractured shale?

7 MR. PETRIE: Within the vertical plane.

8 DR. KINGHAM: Does that mean the
9 equipotential 120 should in fact curve down to the
10 right to correspond to what you are telling us?

11 MR. PETRIE: That is correct, and if we
12 were to see a pattern of upward flow indicated by the
13 120 contour, then I would expect to see it coming down
14 at some angle to the highly fractured shale and
15 approximately vertical through the highly fractured
16 shale and then have the opposite slope indicating a
17 component of upward flow at that point to the highly
18 fractured shale.

19 However, I am unable to draw the contour
20 in that position because I have a water level here,
21 here being piezometer 1 of HC6, which has a water
22 elevation of 118.37. Were that value, piezometer 1 at
23 HC6, in excess of the value at piezometer 2 for the
24 same borehole, being 120.86, then indeed that could
25 curve the contour the other way.

Agree X
draw out figure to
scale



1 MR. McQUAID: Q. What is this, or what
2 is contradicting what, or what conclusion do we draw
3 from this?

4 MR. PETRIE: A. I conclude from the
5 figure that based on the water level data I cannot see
6 the hydrogeologic zones as postulated by Trow.

7 MR. HODGSON: Could we go back and if
8 the witness for the record could draw in a different
9 colour on this figure the various arrows he gave in
10 response to Dr. Kingham's question. That might be
11 useful because he drew it with his pointer.

12 MR. McQUAID: Q. Those were the lines
13 you would expect to see if in fact the highly fractured
14 zone were there.

15 MR. PETRIE: A. Yes. I will draw the
16 120 metre contour in the pattern I would expect if the
17 highly fractured shale acted as a major drain for the
18 site. I guess I should indicate that like this. I am
19 putting some hatched marks on this line so that when we
20 Xerox this it will be easier to see the different
21 lines. I have indicated in blue on the legend which I
22 take it is B-621, I have indicated the 120 metre
23 contour if the unit 4, the hydrogeologic unit, is
24 present as defined.

25 Q. Can I ask you to look at page 33



1 of the report and relate your comments and that
2 drawing, the blue line you have just drawn on B-621 to
3 the text we see there. I am looking at the first full
4 paragraph. Is that the same observation?

5 A. In part, but there is another
6 point here I have not addressed. The second sentence
7 reads: "In addition, at HC4 ..." referring to the
8 first complete paragraph on page 33:

9 "In addition, at HC4 steep downward flow
10 is apparent only in the lower portions
11 of the weakly fractured massive shale
12 (Unit 3) and not completely across this
13 unit as is expected. "

14 I am referring to the two piezometers at HC4, being
15 piezometer 2 and piezometer 3. Piezometer 2 is
16 screened at approximately 4 metres, that is my
17 estimation reading from the elevations scale on the
18 left, approximately 4 metres below the top of the
19 weakly fractured shale and yet it has a very similar
20 pressure head or water level as the well screen
21 immediately above it, being piezometer 3 at HC4.

22 We were to have uniform downward flow
23 from unit 2 being the moderately fractured shale at HC4
24 to unit 4 being the highly fractured shale at the base
25 of HC4, I would have expected a lower water level at



1 that screen being piezometer 2 in HC4.

2 What I see is a component of horizontal
3 flow in the domain of HC4, being piezometers 2 and 3,
4 as evidenced by the similar water levels I see at those
5 two well screens.

6 Q. On page 33 you refer to a concept
7 or an expression of small scale complexity?

8 A. Yes. There are a number of other
9 piezometers drilled at this site in which the number of
10 water level measurements one could obtain in any one
11 vertical profile are in excess of these developed by
12 Trow, but for the Trow installations we have
13 measurements for 4 or 5 points in the vertical profile
14 and that is the more standard piezometer installation
15 used by most consultants.

16 Miss Hewetson in her work at the
17 University of Waterloo and reproduced in her thesis,
18 the installations which she installed, being the WAT
19 series of installations, had as many as 12 points in
20 any one vertical profile which could provide a
21 measurement of the water level data. We reviewed that
22 water level data in order to assess the pattern of flow
23 at this site.

24 Page 34 provides a measure of these
25 data. Page 34 is Figure B.3.5, it is a series of three



1 graphs and I would start at the bottom to point out one
2 thing. The left-hand series of graphs indicates the
3 sources from Trow, H-40A, and that is the water level
4 data obtained in April of 1986. The right-hand three
5 graphs were adapted from Miss Hewetson's thesis, being
6 Exhibit E-214.

7 Q. We could draw a line down the
8 centre of the page and those to the right of the line
9 are from Miss Hewetson's report and those to the left
10 are from H-40A, the Trow report?

11 A. Correct. I should refer to the
12 information at the top. On the far left-hand side we
13 have a schematic picture of the borehole in question
14 and for the top series of graphs it is WAT 3 and we
15 have shown a small square under the heading of sample
16 interval indicating that the open area of the well
17 screen or piezometer at that point at which the value
18 being adjacent to that is in brackets is the water
19 level measured and these numbers refer to Trow's
20 measurements of April of 1986.

21 Going down the scale on the left we see
22 128.21 and there was some question as to the validity
23 of that point, but would refer to the second one,
24 123.29. If you go across to the graph on the right,
25 that line ends at the elevation of, referring to the



1 scale across the top, of 123.29 and so the horizontal
2 scale across the top of these figures is a measure of
3 the water level measured at each point indicated on the
4 vertical rendition of the borehole to the left of the
5 figure.

6 So, if I could draw a line quickly on
7 here, the well screen I am indicating being WAT-3-2 but
8 which lies at an elevation as thus and the water level
9 is indicated by the number in brackets, 123.29, which
10 is approximated or indicated by the value at the top of
11 this graph.

12 We have then drawn the line you see on
13 the left-hand graph, again referring to WAT-3, at each
14 point for which we have data, the data indicated by the
15 value in brackets on the far left and we end up with a
16 squiggly line. This squiggly line has some meaning.
17 Where we have points which move to the left, and now I
18 am referring to the bottom where the line moves sharply
19 to the left and stops, it has a water level elevation
20 in the order of 115 and we see a low pressure zone
21 there. A low pressure zone may indicate a more highly
22 conductive zone or a zone of rock in which the
23 permeability or the hydraulic conductivity may be
24 higher.

25 That is indicated because I read from



1 this sloping line that there would be a component of
2 downward flow toward that piezometer from the overlying
3 strata.

4 We compared that to the data provided by
5 Miss Hewetson in Exhibit E-214 and I wish to point out
6 that in Exhibit E-214 the value for the water levels
7 was not provided. What we have done is photocopied a
8 figure in her report and reproduced it to give us this
9 contour pattern or pressure head profile pattern. I am
10 now pulling out Exhibit E-214-D5. This is taken from
11 Miss Hewetson's thesis and I understand it is Drawing 5
12 from the exhibit number and I would refer to the
13 bottom, a series of what I would call pressure head
14 profiles, essentially squiggly lines relating the water
15 level at the elevation measured. We photocopied those
16 data, the third one from the left being WAT-3, but we
17 photocopied that data and reproduced it on this scale
18 in order to juxtapose it to the data we had taken from
19 Trow.

20 So, on the right-hand figure we have
21 data taken from -- the date of Miss Hewetson's thesis
22 is 1985 and I don't have it at my fingertips the date
23 where the water levels were recorded. But, I would
24 draw your attention to a comparison of these data.
25 Looking at the shape of those lines, they appear to



1 show a general conformity except for the points at the
2 bottom, the bottom being the lowest mark indicated on
3 each of these graphs where during Miss Hewetson's
4 reading you have a water level that should be in excess
5 of 125 as I read that from the top graph, and in the
6 Trow data we have a value, and I am reading from the
7 far left, of 115.80.

8 We undertook the same exercise for
9 another piezometer, being WAT-5, and the Trow data
10 being the graph on the left which gives us a rather
11 smooth line and with not a lot of kinks and bumps in
12 it, but generally at an elevation of around 125 metres
13 above sea level and it is not so dissimilar from the
14 line provided by Hewetson, and the Trow line is a bit
15 more smooth and the Hewetson line has a few more small
16 kinks to it.

17 In this flow regime, I would interpret
18 the dominant flow direction is probably lateral given
19 that the water level is essentially the same at that
20 vertical profile.

21 The bottom figure is the data obtained
22 from WAT-7. On the left we have the Trow data as
23 indicated in Exhibit H-40A and we have low pressure
24 zones referring to elevations of 182.98, being the
25 second to most bottom piezometer, and above and below



1 that zone we have water levels at a higher elevation.
2 It is my interpretation from this pattern that the
3 elevation of 102.98 describes or is in close proximity
4 to the zone in which groundwater flow may be more
5 rapid.

6 In other words, I see a pattern of
7 groundwater flow converging from beneath to this zone
8 and from above to that zone and this well point may be
9 within or adjacent to a zone of more transmissive
10 groundwater flow. I note there are similar groundwater
11 flow patterns up here with a downward component of flow
12 across the uppermost four piezometers; piezometers 5
13 and 6 both with similar water levels, both in the area
14 of 110.5, and beneath that is a higher water level of
15 112.55.

16 The zone across 110.5 in my mind
17 describes a zone in which lateral groundwater flow may
18 again dominate with a subtle upward component of flow
19 to this zone and a downward component of flow to this
20 zone.

21 I compare this pattern with that
22 generated by Miss Hewetson, and I see in the area I
23 just indicated, being the elevation of 110.5, I see it
24 as a low pressure zone on the Hewetson data, and I also
25 note in the Hewetson data this point appears to be at



1 an elevation of less than 105, so during the time
2 sequence between these recordings we see a 5 metre rise
3 in the water level in the Trow data.

4 Those piezometers there, being the 5th
5 and 6th ones down, may define a zone of lateral
6 groundwater flow and again with a component of vertical
7 flow from above and beneath converging on that zone. I
8 see at the bottom of the Hewetson figure a zone of low
9 pressure as indicated by a groundwater elevation of in
10 the order of 95 metres or less where at the same time
11 in the Trow data I see an elevation of 10 or 15 metres
12 in excess of that, being 109.26.

13 This is a low pressure zone, this being
14 the second to bottom piezometer in WAT-7 as defined by
15 Trow and I do not see this same pattern when I compare
16 the same elevation to the data provided by Hewetson.

17 The point of this review was to see if
18 we could find or interpret from these pressure head
19 profiles the hydrostratigraphy as presented by Trow.
20 Where I see these low pressure zones, where they are
21 bounded above and below by zones of higher pressure, it
22 is my interpretation that we do see an element of
23 horizontal groundwater flow. What I do notice is that
24 comparing between different sets of water level data,
25 the pattern in some places is consistent, again



1 referring to the 5th and 6th piezometer down in WAT-7,
2 and in some places inconsistent, referring to the
3 lowermost piezometer in WAT-7.

4 My review of this water level data,
5 being these small scale pressure head profiles, and I
6 do not see there are different zones, hydrogeologic
7 zones as postulated by Trow. I see a complex pattern
8 of groundwater flow in which the data are not
9 necessarily reproduced from one monitoring event to the
10 other and in which nearby boreholes, referring to WAT-5
11 being really so far away from WAT-3, the uppermost two
12 on this graph, I see quite different pressure head
13 profiles.

14 I could relate the position of these two
15 from Exhibit E-214-D5, and I am locating WAT-3
16 essentially in the middle of the diagram, and we by-
17 pass WAT-4 and then get to WAT-5. Is that correct?
18 Yes, WAT-3 and WAT-5 are quite close together on the
19 scale of this drawing and yet the pressure head
20 profiles between them are very different and again on
21 WAT-7, which is halfway down toward the property
22 boundary, we have quite different profiles from that
23 developed at WAT-5.

24 Q. Can you account for these
25 variations as a hydrogeologist, Mr. Petrie? What do



1 they tell you as a hydrogeologist?

2 A. A number of things may give rise
3 to it. Sampling events may have interfered with the
4 water levels, low permeable strata, and the water level
5 in low permeability strata may take some time to
6 achieve equilibrium conditions and the other point is
7 that I see a complex pattern of groundwater flow. I do
8 not see a clear delineation of the groundwater flow
9 patterns between these various profiles.

10 I interpret these profiles to indicate a
11 complex site which is not easily delineated on the
12 basis of water level data alone.

13 MR. McQUAID: Mr. Chairman, at this
14 point this would be a convenient time as I went on a
15 little longer than I expected, but we did finish a
16 section.

17 MR. LANCASTER: Very well. Ten minutes
18 or so.

19 ---Recess

20 MR. LANCASTER: Please be seated.

21 MR. McQUAID: Q. Mr. Petrie, just to
22 backtrack for a moment to page 34, you referred to
23 these head profiles and explained that the various
24 lines mean an area of low pressure, and that is one I
25 took down particularly. I wonder if you could, more or



1 less, describe for us by reference to some kind of a
2 legend if we see a vertical line or we see a kink or
3 triangle to the left, what that means and one to the
4 right and so on. Could you give us an indication of
5 how we could read these?

6 MR. PETRIE: A. Certainly. I have put
7 Figure B.3.5 back up on this overhead and at Mr.
8 McQuaid's suggestion I can amplify on the meaning of
9 these lines. Where we see a line that slopes in a
10 manner like thus indicated...

11 Q. You are in indicating in the WAT-3
12 category or block?

13 A. Correct. Just a sloped line from
14 top left to bottom right and I would say that that is
15 some sort of component of downward flow.

16 Q. Can you put downward opposite
17 that?

18 A. I will put a little dashed arrow
19 indicating downward. Where I see a break in the slope
20 of this line ...

21 MR. HODGSON: Before the witness marks
22 up the exhibit too much, I would ask that he consider
23 what he just said.

24 MR. McQUAID: I think Mr. Hodgson is
25 questioning whether you mean downward on that



1 particular slope.

2 MR. PETRIE: I am indicating that where
3 I see a break in the slope of a line like that

4 MR. McQUAID: Q. Going from right to
5 left?

6 MR. PETRIE: A. I have joined up two
7 lines approximately at right angles and where I see a
8 break in a slope like that I would expect to see a
9 component of lateral flow at that point, at the break
10 in the slope.

11 Q. At the every point?

12 A. At approximately the point,
13 correct.

14 DR. KINGHAM: I am afraid I am going to
15 have to ask you to explain that as well. Where you
16 have a line with a negative slope, as you have shown
17 for that upper segment from 120 to 130, you have a
18 hydrostatic head of 130 at depth, but only 120 at a
19 less shallow depth and does that not correspond to
20 upward groundwater flow in that segment of the line?

21 MR. PETRIE: You are quite correct.

22 DR. KINGHAM: I think that that is
23 really the question.

24 MR. PETRIE: This doesn't even rub out
25 on this acetate.



1 MR. McQUAID: Q. Cross it out or put
2 the arrow on the top.

3 MR. PETRIE: A. I will cross out that
4 whole segment and take an example further down here at
5 WAT-7. Where I see the horizontal line, and I am now
6 marking on the overhead, but I would expect to see a
7 component of lateral flow. Where I see sloping lines I
8 would expect to see a component of vertical flow.
9 Where the lines converge, I would expect to have within
10 the vertical plane downward flow and beneath it I would
11 have upward flow.

12 To repeat that, the vertical line
13 essentially indicates horizontal flow and a sloping
14 line either upward or downward, depending on the
15 relative pressure head or water level on either side or
16 either end of that line, and where the lines break or
17 converge at different angles, I would similarly expect
18 to see a break in the groundwater flow pattern.

19 Thus, when I look at these figures, for
20 example WAT-7, the bottom of the one here, I see a
21 variety of flow directions, the variety being
22 horizontal at some locations where the flow lines are
23 vertical or again where I have converging flow I would
24 expect to see a component of horizontal flow, for
25 example, at that point and where I have sloping lines I



1 have flow dominated in the vertical plane.

2 I notice when I compare the Hewetson
3 data with the Trow data again at WAT-7 there is an
4 inconsistency in the pattern between those two wells.
5 Were the site to be or were the hydrogeologic
6 definition of the site as proposed by Trow to be
7 uniform across the site, and I can refer back to B-620,
8 a system dominated with moderately fractured shale at
9 the surface of the rock and extensive weakly fractured
10 shale being hydrogeologic zone 3, highly fractured
11 shale zone 4, and a moderately fractured shale zone,
12 zone 5, I would expect to see a more uniform pattern of
13 flow -- a more uniform pattern of head profiles at two
14 different events or points in time and again in
15 different points in space, i.e., the other wells we
16 have being WAT-5, WAT-7 and WAT-3.

17 To repeat, were we to have a uniform
18 hydrostratigraphy or the hydrostratigraphy as defined,
19 I would expect to see a more uniform pattern of
20 hydraulic head profiles, uniform in time and uniform in
21 space. What I see is a highly complex pattern of
22 groundwater flow where I see small scale reversals,
23 where the water level pattern or flow direction changes
24 from down to up and where I also see some zones of
25 horizontal flow.



1 Based on my review of these data as
2 provided in this figure and again on the previous
3 figure, the previous figure being the hydraulic head
4 data presented on page 32, being Figure B.3.4, I do not
5 see the hydrostratigraphy or the hydrostratigraphic
6 layers as proposed by Trow, I see a complex pattern of
7 flow which is not reproduced readily from one well to
8 the next in space, that is, nor in time as I referred
9 to the Hewetson data and the Trow data for Figure
10 B.3.5.

11 Q. All right. Now, could we continue
12 at page 35, section B.3.3, hydraulic gradients?

13 A. The hydraulic gradient data is
14 essentially a synthesis of the water level data in
15 which one takes the water level at a point or the
16 separation of water level data at two adjacent points,
17 and I am pointing out to two water well screens in
18 piezometer 3, and we take the difference in water level
19 as measured at those two points and divide it by the
20 separation between those two points to arrive at the
21 measure of the hydraulic gradient between those two
22 points.

23 We have undertaken to do that, to
24 determine the vertical hydraulic gradients at each of
25 the well nests at the site, and we have provided those



1 calculations in Appendix A of this report.

2 Q. We see on page 35 a reference to
3 Appendix I?

4 A. Appendix I, yes.

5 Q. Should we correct those appendices
6 to the separators, Appendix A?

7 A. Correct. Appendix A, as per the
8 tab, is Appendix I.

9 Q. I am looking at the separator or
10 index for Appendix A and I see, as you have noted,
11 Appendix I is immediately behind there, vertical
12 hydraulic gradients, and then you have numbered the
13 pages down in the lower right-hand column I-1 through
14 I-9, correct?

15 A. That is correct.

16 Q. What is it your were doing? You
17 made some reference to page 34, but have you actually
18 calculated the vertical hydraulic gradients for each of
19 the boreholes here?

20 A. We have. Referencing the first
21 page, being I-1, down the left-hand side we have the
22 well number and referring to the first well nest, it is
23 HCl-1-85, HCl-2 and HCl-3 and going over to the next
24 column for which we have provided data, we have a
25 heading "Top of Screen" and the next is "Bottom of



1 we have taken a water level at well nest HCl-1 and have
2 said it was applied at an elevation, being the midpoint
3 elevation, of 156.35. So all the water level data
4 recorded for HCl-1 is representative of an exact
5 elevation of 156.35. Again for HCl-3 the water level
6 is the elevation at which it is measured.

7 The next series of columns are indicated
8 by dates and over to the far right we have the heading
9 of water level. These data are provided first for the
10 far right-hand column being headed the 15 of April,
11 1986 and the 15th of April, 1986 water level data are
12 provided by Trow in Appendix 5, I believe, of Exhibit
13 H-40 -- H-40A, yes, correct, Appendix 5 of H-40A, which
14 provides the April 1986 water level data which we have
15 entered.

16 You will see a number of dates starting
17 initially from the 21st of December, 1985 and going
18 through to March of 1986. These data were provided as
19 one of the interrogatory responses requested of Trow
20 after this report came out. I am just trying to find
21 the exhibit. They were provided in the interrogatory
22 to Weir & Foulds and I believe that the exhibit
23 number ...

24 Q. Either H-84 or H-85?

25 A. Correct, one of the two. There



1 were two interrogatories, one to Weir & Foulds and a
2 second to the Canadian Environmental Law Association
3 and, as Mr. McQuaid has pointed out, these were
4 Exhibits H-84 and H-85. I have taken the data ...

5 Q. Weir & Foulds is the H-84 one.

6 A. I have taken the data from H-84,
7 the H-84 interrogatory, and transposed it as you see
8 here under the heading of water levels.

9 DR. KINGHAM: Have you just photocopied
10 this or just re-entered them all?

11 MR. PETRIE: We re-entered them.

12 DR. KINGHAM: Could you look at HC3-1-85
13 in March and April of '86 and is that a typo?

14 MR. PETRIE: HC3-1-85?

15 DR. KINGHAM: March and April of 1986.

16 MR. PETRIE: Under March I see 126.92
17 and 126.79.

18 DR. KINGHAM: That doesn't correspond to
19 anything else on this entire table and I thought we
20 might as well get it right.

21 MR. PETRIE: I am now looking at H-40A,
22 Appendix 5, the water level data for April and I see
23 under HC3-85, piezometer 1, going over the far right-
24 hand side 126.79 and now I am just referring back to
25 the Weir & Foulds H-85 submission.



1 MR. McQUAID: Q. H-84?

2 MR. PETRIE: A. I beg your pardon, H-
3 84, and HC3-1-85, yes, there is a ten-foot change
4 recorded in this data set and the 24th of March data is
5 126.92 which is the number you see before you in
6 Appendix 1 under HC3-1 for March, water level data.

7 Then I go to the previous month, being
8 the previous measurement, the 9th of March, 1986, and
9 see a value entered as 137.73. These are metres of
10 elevation and I may have said feet.

11 Q. In answer to Dr. Kingham's
12 question, the data is correctly taken from the exhibits
13 and I guess the next question is can you account for a
14 10-metre differential over that one month period?

15 A. I cannot account for a 10-metre
16 elevation differential.

17 DR. KINGHAM: I thought perhaps the
18 number ought to have been 136.92 and 136.79, but I
19 don't know. It sticks out like a sore thumb.

20 MR. PETRIE: Yes. I am taking the
21 numbers as provided by Trow.

22 MR. McQUAID: Q. What is not clear to
23 me, Mr. Petrie, is that you have these numbers and
24 there is a series of vertical gradients, the numbers
25 with the minus signs in front of them?



1 MR. PETRIE: A. Correct. If I could
2 refer you to the headings of top of screen and bottom
3 of screen, and again referring to HC-1 for convenience,
4 and go down three sets of lines and there is an entry
5 of vertical gradient. To the right of that I have
6 three sets of numbers in brackets, 1-2 being the first
7 entry, 1-3 being the second entry and 2-3 being the
8 third entry. Those are the piezometers or the pair of
9 piezometers over which the vertical gradient has been
10 measured. It would be more convenient if I referenced
11 HC-4 and then I can put up the water level data as per
12 the figure we referenced earlier, B.3.4 on page 32 of
13 our report.

14 For convenience I am now referencing
15 borehole HC-4. Again under the heading of vertical
16 gradients for the well nest HC-4 I have a sequence of
17 brackets and the first entry being 1-2, 1-3, 1-4, 2-3,
18 2-4, the last entry being 3-4. What those symbols
19 refer to is the piezometers at which the water level
20 gradients have been calculated. For example, the first
21 entry being 1-2, we have taken piezometer 1 and
22 piezometer 2 and have subtracted the water level data
23 and come up with a water level differential and have
24 divided it by the screen separation.

25 At this point, as I referenced earlier,



1 we are referencing the mid screen elevation. In other
2 words we are saying specifically for HC4-1 that the
3 water level or the pressure head being 122.96 is
4 representative of the midpoint of the screen at
5 piezometer No. 1.

6 So, looking across that line where we
7 have the vertical gradients and (1-2) we see a sequence
8 of negative numbers reading left to right and the first
9 one being negative 0.795 and we go across the page and
10 we see a sequence of negative numbers. That negative
11 number is an indication that the groundwater flow
12 between those two piezometers is downward. Where we
13 see positive numbers -- I am sorry, the absence of
14 a negative sign, we have the indication that at the
15 pair of piezometers in question groundwater flow in the
16 vertical plane would be directed upwards.

17 DR. KINGHAM: In light of what you just
18 said a minute ago, we should for the time being reserve
19 judgment on the five numbers beneath the 24th of March,
20 1986 and the 15th of April, 1986, the pairs of
21 piezometers 1-2, 1-3 and 1-5.

22 MR. PETRIE: Correct, and that being
23 because of the uncertainty attached to that pronounced
24 change in water level at that period of time. Again
25 referring to HC-4, that well nest, we took the gradient



1 between piezometer 1 and piezometer 2 and also looked
2 at the vertical gradient between piezometer 1 and
3 piezometer 3 and that is done by ignoring piezometer 2
4 and taking the water level difference between
5 piezometer 1 and piezometer 3 and dividing by the
6 separation of the mid screens.

7 When we look at the entry adjacent to
8 HC4-4 and again I am referring to the first series of
9 columns where we have the entry of top of screen, an
10 entry for the bottom of screen and rather than an entry
11 at the mid point we have w.t. I can explain that with
12 reference to the figure we have on the overhead, B.3.4.
13 I am referring to HC-4, piezometer 4 where the water
14 level elevation is measured at 135.44, and that is
15 metres above sea level.

16 Rather than as we have done for the
17 deeper piezometers, rather than indicate that that
18 pressure head is representative of the mid screen
19 point, and I am indicating approximately the mid screen
20 of that piezometer, we have said that that elevation of
21 135.44 is representative of the elevation at which it
22 was measured.

23 MR. McQUAID: Q. Is this standard
24 practice or accepted practice?

25 MR. PETRIE: A. It is. Where it falls



1 down a little is that for some of the screens, some of
2 the water levels lie outside the domain of the screen
3 and we also indicated for the uppermost screens the
4 water table is where it is measured and we have not
5 related the position of the water level to the mid-
6 point of the screen and so we are being consistent
7 across the board in determining our vertical gradients
8 at this site.

9 Q. Why are you looking at the
10 vertical gradients?

11 A. The pattern of vertical gradients
12 gives us a measure of the direction of groundwater
13 flow, and referencing Figure B.3.4 on the board, we
14 would expect to see steeper vertical gradients in the
15 area of the hydrogeologic unit component as proposed by
16 Trow, unit 3, and we would expect to see steeper
17 gradients here and much less steep ones vertically in
18 these zones here.

19 Q. When you say "here" and "these
20 zones here"?

21 A. The highly fractured shale. We
22 would also expect to see an indication of the
23 significance of the discharge zone till. The discharge
24 zone till is that portion of overburden materials that
25 lie on the downgradient extremity of this site and



1 under Highway 403. It was this area where Trow
2 postulated they had groundwater discharge principally
3 from the highly fractured shale, and in that case we
4 would expect to see upward hydraulic gradients in this
5 area, this area being between HC8 and HC14 as the only
6 wells we have shown on this cross-section. When we
7 look at the hydraulic gradients for HC14, they are
8 contained in the table I-4 and it is the last entry on
9 the page starting with HC11 at the top. HC14 at the
10 bottom of the page has the four piezometers and the
11 same set of headings, top of screen, bottom of screen
12 and the mid-point elevation of the screen.

13 We, however, only have two sets of water
14 level data for this well as provided for Trow, one in
15 the interrogatory and the second in the appendix to the
16 report, H-40A, and the two sets of data are indicated
17 for the 24th of March and the 15th of April, both of
18 1986, and we have two sets of water levels and two sets
19 of gradient data.

20 You will notice that all the gradient
21 data there are negative and a negative vertical
22 gradient indicates downward flow. I can observe that
23 from looking at the pattern of water level data here.
24 The shallowest piezometer being piezometer 4 at HC14
25 has the highest water level of 109.14 and the next most



1 deep piezometer, piezometer 3, is 108.63, and
2 piezometer 2 is 108.32 and piezometer 1 is 108.31.
3 Within the vertical plane groundwater flow is directed
4 downward. I would draw your attention to the subtle
5 difference between the lowermost two piezometers
6 suggesting that the vertical gradient at this point is
7 not particularly strong.

8 However, I wish to refer to a second
9 borehole on the previous page which is I-3 and the
10 borehole I wish to refer to is HC9 and I think I can
11 locate that for you on a plan here. I don't have a
12 plan view of the wells, but I can refer to an overhead
13 I referred to earlier this afternoon, Figure B.3.1.
14 HC9 is located downgradient and south of Highway 403 in
15 close proximity to MB-18. This is also the area of the
16 discharge zone as defined by Trow in H-40.

17 I would draw your attention to the
18 larger drawing in the upper corner, or the larger scale
19 drawing; HC15, HC14 and HC9 all lie south of 403 and
20 the discharge zone as defined by Trow at the
21 approximate area in the vicinity of HC9, and not
22 exactly at HC9, but at HC9 I would expect to see upward
23 hydraulic gradients from the bedrock if indeed we were
24 to have groundwater discharge from the bedrock to
25 surface.



1 With reference to the vertical gradients
2 at HC9 on Appendix I-3, if you cast your eye across
3 where we have the vertical gradient 1-2, this gradient
4 is measured at the deepest pair of piezometers at
5 borehole HC9. You will notice as you run your eye
6 across that page they are all negative values and that
7 is across that page where I have (1-2) and moving
8 sequentially to the right. I have a couple of large
9 gradients there and looking at the date for the 18th of
10 January, 1986 being negative 1.236 and again for the
11 6th of February being negative 0.0524. I would
12 disregard those excessive gradients because I suspect
13 the wells were sampled at that point in time and we are
14 seeing a slow recovery of the water levels.

15 Ignoring those data I generally see the
16 vertical hydraulic gradient is on the order of 0.1
17 directed downward and we can see the same thing if we
18 can look at piezometer nests 2-3, HC9-4 being the well,
19 and when I look over at the vertical gradient under the
20 bracketed sequence of numbers looking at the line
21 starting with (2-3), again I see negative values right
22 across the line, and some of them are rather low, but
23 they are all negative values, a negative value as I
24 indicated being downward flow. I would expect to see
25 that were we to have a groundwater discharge zone here



1 from the bedrock, and I emphasize from the bedrock,
2 that we would see upward vertical gradients at those
3 points.

4 Q. Going back to the text at page 35,
5 you indicated that the gradients were provided in
6 Appendix 1 and in general these data show strong
7 downward gradients on-site with values in excess of 0.2
8 and some even in excess of 0.5?

9 A. That is correct.

10 Q. Then you make an observation of
11 the downward gradients being less steep immediately
12 south of Highway 403?

13 A. That is correct. In the area of
14 the discharge zone as defined by Trow, we would have
15 expected to have seen upward hydraulic gradients, but
16 we see downward hydraulic gradients, and I give the
17 general number being generally less than 0.05, and the
18 last sentence on page 35 refers to those boreholes
19 located out in Aldershot, i.e., further to the south,
20 and the hydraulic gradients are sub-horizontal with
21 some upward gradients encountered. A sub-horizontal
22 gradient means that the value for the vertical
23 hydraulic gradient is approximately zero, neither
24 positive nor negative.

25 Q. Can you, with reference to the



1 overhead that is there, Figure B.1.1, indicate what
2 nests or wells you are referring to?

3 A. For the off-site wells I was
4 referring to HC10, HC11 and HC12 where there is a
5 component of vertical flow measure at some points in
6 time. On page 36 we summarize our review of the
7 vertical hydraulic gradient data available and I have
8 three headings and I wish to speak to each one.

9 Under heading 1, we see strong downward
10 gradients measured within and below the highly
11 fractured shale, and I reference HC5, HC6, HC8, HC9,
12 MB-13 and MB-16. Now I am returning to Figure B.3.4 on
13 page 32 and we have HC6 and HC8 which are both
14 indicated on that cross-section. I am referring to the
15 strong downward gradients I see at the bottom of HC6
16 and below -- at the bottom of HC8.

17 Where we do have a highly fractured
18 shale unit with a significant hydraulic conductivity as
19 postulated by Trow, I would expect to see a component
20 of upward flow at this point, this point being between
21 the bottom and the secondmost bottom piezometer in HC8.
22 The hydraulic conductivity data we reviewed just
23 provides a magnitude of the slope of the potentiometric
24 lines we have interpreted, and I am now referring to
25 the blue line again from B-621 where had -- where were



1 there a highly fractured shale zone as defined in this
2 base drawing, I would expect to see a component of
3 upward flow at this point and the contour pattern would
4 be significantly different from that which I have
5 contoured using the available data.

6 It is my interpretation that the
7 hydraulic conductivity -- pardon, the hydraulic
8 gradient data would not allow you to delineate four
9 hydrogeologic units at this site as postulated by Trow.

10 Referencing point two on page 36, we see
11 more modest or low downward gradients encountered
12 within the weakly fractured shale, that being
13 hydrogeologic unit 3 at HC4 and HC6. Were this zone to
14 act, this zone being the weakly fractured massive
15 shale, hydrogeologic unit 3, and were this unit at
16 borehole 6 to provide a low permeable zone at this
17 point, we would expect to see a higher hydraulic head
18 across unit 2 and with most of the hydraulic head loss
19 or steepest hydraulic gradient across this, but I see
20 very little hydraulic head contrast across zone 3 and
21 see more pronounced hydraulic head contrast within zone
22 2.

23 Point No. 3 on page 36 I referenced
24 earlier, where we see pronounced downward gradients
25 off-site adjacent to the discharge zone, the discharge



1 zone as postulated by Trow. By reference to HC9
2 between piezometer 1 and 2 we have downward gradients
3 of 0.1 and were there a discharge zone from the bedrock
4 at this point, we would expect to see upward hydraulic
5 gradients, but I do not see upward hydraulic gradients
6 and I do not see any hydraulic evidence based on the
7 water levels and the gradient data of groundwater
8 discharge from the bedrock to surface at HC14 or at any
9 of those wells in this area.

10 Q. All right. Then let's turn to the
11 next data which you examined on page 36 where there is
12 a heading of B.3.4, hydraulic conductivity?

13 A. In an attempt to again examine if
14 the hydrogeologic units as proposed by Trow can be
15 defined as they have undertaken them, I have examined
16 the hydraulic conductivity data provided by Trow and
17 plotted that same data on the cross-section provided on
18 page 37, being Figure B.3.6. That is the overhead you
19 see here. Now, these data, or the hydraulic
20 conductivity data, was taken as is noted under source
21 as No. 3 at the bottom of the page, the hydraulic
22 conductivity data was taken from Trow Appendix 11 of
23 Exhibit H-40A, the appendices to the Site F report.

24 With reference to the legend we have two
25 sets of data. To the right-hand side of the well



1 screen, in this case in the legend it is 8.3×10^{-5} .
2 That is the hydraulic conductivity in centimetres per
3 second and as measured at the well screen adjacent to
4 which that number is written and the method of
5 determination of this hydraulic conductivity was the
6 slug tests or the Hvorslev tests that have been
7 referenced earlier.

8 On the left-hand side, and still
9 referring to the legend, of the borehole axis, we have
10 a number in square brackets and we have a vertical line
11 adjacent to that, adjacent to the right-hand side but
12 that line is chopped off at the top and bottom. That
13 value, and I am referring to 1.6×10^{-5} is the
14 hydraulic conductivity in centimetres per second
15 determined from the pressure packer tests and the
16 vertical line adjacent to that number describes the
17 vertical interval over which that pressure packer test
18 was conducted and so that number is representative of
19 that vertical interval defined by that line.

20 If I start at HC4, being the upgradient
21 well or the upslope well indicated on the cross-
22 section before you, I see we have values for the
23 hydraulic conductivity on the right-hand side of that
24 borehole axis as determined by slug test data and we
25 have values of 2.6×10^{-5} , 8.3×10^{-5} and 5.6×10^{-5}



1 for the lowermost piezometer at that well.

2 Q. You said 5.6×10^{-5} and did you
3 mean 10^{-6} ?

4 A. It is 10^{-6} , my mistake,
5 5.6×10^{-6} for the lowermost piezometer. On the left-
6 hand side of that borehole index I have three vertical
7 segments delineated uppermost by a hydraulic
8 conductivity of 1.2×10^{-3} and then beneath that in
9 square brackets we have a value of zero and thirdly,
10 1.6×10^{-5} .

11 It is my recollection that the value of
12 zero did not initially appear in the appendix provided
13 by Trow, Appendix H-40A but was subsequently indicated
14 thus in cross-examination, and secondly the value of
15 1.2×10^{-3} was also or appears to be a correction from
16 that which initially appeared in the appendix. Just
17 comparing the values determined by the pressure packer
18 data on the left of borehole HC4 with the values
19 generated from the slug test data indicated on the
20 right-hand side of borehole HC4, we see some
21 interesting comparisons.

22 For example, at HC4, No. 3, we have a
23 slug test value in the order of 10^{-5} whereas the
24 pressure packer test on that interval gave us a value
25 of 10^{-3} .



1 Q. I am sorry, I am not sure. This is
2 at screen 3?

3 A. I am referring to screen 3 of
4 piezometer HC4.

5 Q. All right. On the right-hand side
6 I see the slug or Hvorslev 2.6×10^{-5} ?

7 A. Correct. That is indicative of
8 the hydraulic conductivity as tested at this well
9 screen.

10 Q. All right. What do I compare it
11 to on the packer test?

12 A. On the left-hand side there is a
13 vertical bar which straddles that well screen and
14 extends a little bit above and a little bit below and
15 the value of the hydraulic conductivity presented
16 adjacent to that is 1.2×10^{-3} . I would draw the
17 Board's attention to the different values determined
18 for the hydraulic conductivity over essentially a
19 similar portion of rock in comparing the two test
20 procedures.

21 It is to be noted again at HC4,
22 piezometer 2, to the right-hand side we have a
23 hydraulic conductivity from slug tests of 8.3×10^{-5}
24 and to the left-hand side over essentially the same
25 vertical interval we have a value of 1.6×10^{-5} , a



1 lesser discrepancy between the two test methods over
2 similar portions of rock. Now, my reason for drawing
3 this to the attention of the Board is to highlight some
4 of the uncertainty in the meaning of the hydraulic
5 conductivity data generated by, (a), the packer test
6 and, (b), the Hvorslev tests.

7 Borehole HC6 provides the most complete
8 profile of hydraulic conductivity data developed by
9 Trow at this site. On the right-hand side of the
10 borehole axis we have the values for the hydraulic
11 conductivities from slug tests and on the left-hand
12 side we have a complete sequence of pressure packer
13 tests, and when I say complete sequences the vertical
14 profile was tested from essentially the top of rock
15 almost to the bottom of the hole in approximately 3
16 metre segments. Each 3 metre zone was tested and the
17 value of the hydraulic conductivity was assigned to
18 that zone.

19 You will note for piezometer 4 at HC6 we
20 have 5.8×10^{-6} for the slug test data and the pressure
21 packer test data gives us a value of 6.0×10^{-5} ,
22 approximately a factor of 10 difference.

23 The next two zones give a hydraulic
24 conductivity reported as zero and that is a measure of
25 the water uptake during the test interval, the water



1 uptake of zero as it has been interpreted to provide a
2 measure of hydraulic conductivity equal or less than
3 10^{-8} . That represents the lowest permeable rock
4 encountered in the vertical sequence at HC6.

5 Of interest at borehole HC6 is the
6 hydraulic conductivity data generated within the zone
7 defined by Trow as the highly fractured shale. The
8 pressure packer test data essentially gives a value of
9 1.5×10^{-5} and 3.8×10^{-6} , but the slug test data, the
10 only one available within this zone at borehole HC6,
11 gives a measure of 7.2×10^{-7} .

12 Trow have defined this unit, the highly
13 fractured shale hydrostratigraphic unit 4, initially as
14 having a hydraulic conductivity of 10^{-2} and
15 subsequently in cross-examination a value of 10^{-3} was
16 considered as more appropriate, and that value I
17 believe was used in Trow's computer model being model
18 A, the model reported on in the Site F report, Exhibit
19 H-40.

20 A second model was produced during
21 testimony by Mr. Sobanski and Mr. Beechinor in which
22 the hydraulic conductivity of unit 4 was indicated as
23 being 10^{-4} . As I review the hydraulic conductivity
24 available before me, I see values to 10^{-5} , 10^{-6} and 10^{-7}
25 collected within this highly fractured shale zone.



1 On the basis of the data on this cross-
2 section, and I am referring to all the data within
3 Trow's defined highly fractured shale, 10^{-6} , 10^{-5} ,
4 10^{-6} , 10^{-7} , 10^{-6} and again at borehole HC14 10^{-6} ; I
5 cannot see how one can define the permeability of the
6 highly fractured shale as being 10^{-3} or 10^{-4} as
7 proposed.

8 Q. May I stop you at that point and
9 ask you to go back to the drawing we had, and I think
10 it was the schematic of how the modeling was undertaken
11 by Trow?

12 A. This one here?

13 Q. Right. I think earlier you
14 commented on the fact that Mr. Sobanski or
15 Mr. Beechinor referred to unit 4 as being more
16 appropriately 10^{-3} as opposed to the 10^{-2} and now you
17 have indicated that in fact it was also modelled at
18 10^{-4} ?

19 A. That is correct.

20 Q. Having looked at page 37 as we
21 just have and the results there, could you just
22 indicate your views as to the appropriateness of either
23 one of those three figures?

24 A. 10^{-2} is not an appropriate value,
25 10^{-3} is not an appropriate value and 10^{-4} is not an



1 appropriate value as one can interpret from the
2 hydraulic conductivity data provided from the slug
3 tests and the pressure packer tests as I have
4 reproduced it on this cross-section. That is not the
5 sum of the data provided by Trow, but I have taken a
6 meaningful representation of the data on the cross-
7 sections which we have investigated.

8 Q. Did you reach any conclusion as to
9 what the data, this data might indicate as to the
10 hydraulic conductivity of the units at this particular
11 depth?

12 A. Yes, on page 38 I am referring to
13 the second complete paragraph, the last sentence of
14 that paragraph:

15 "On the basis of the pressure packer
16 test data, CRA concludes that the
17 hydraulic conductivity of this unit ..."
18 that is unit 4 as defined by Trow, the hydraulic
19 conductivity does not exceed the value of 1×10^{-5} . I
20 wish to reiterate a point here. In that sentence I was
21 referring to the pressure packer tested data and in the
22 previous paragraph I referred to the cross-examination
23 of Mr. Sobanski and I am referencing volume 22 of the
24 transcript, page 5111 where Mr. Sobanski indicated that
25 some uncertainty is associated with the interpretation



1 of slug test data. He indicated that because of the
2 effects of borehole smearing, slug test data may not
3 realistically indicate the hydraulic conductivity of
4 the highly fractured shale being his unit 4.

5 Given his concern, and I recognize also
6 there is a concern about interpreting the slug test
7 data where you may have the effects of some sort of
8 borehole smearing or plugging of any fractures because
9 of the action of drilling, that the Hvorslev data may
10 not provide the most meaningful data for fractured
11 rock, and that is why I focused a bit more specifically
12 on the pressure packer tests.

13 The pressure packer tests are undertaken
14 in the borehole prior to the installation of the
15 piezometer and essentially the borehole is isolated by
16 some inflated packers and between that isolated section
17 water is injected in under pressure. One can
18 reasonably expect that the pressure packer data may
19 give a better representation of the hydraulic
20 conductivity over the tested zone than may a piezometer
21 test.

22 In the last sentence in that paragraph,
23 that paragraph being the first paragraph on page 38,
24 I make the statement:

25 "It should noted that reasonable



1 through the vertical length of the borehole. The
2 additional hole was HC3 where similarly I believe three
3 pressure packer tests were conducted. Slug test data
4 is available for virtually the bulk of the site and
5 interpreting hydraulic conductivity characteristics of
6 this site I used the slug test data. Where I had both
7 sets of data I placed more reliance on the pressure
8 packer test data and that leads me back to the
9 statement I made earlier with respect to the second
10 paragraph on page 38, the last sentence:

11 "...CRA concludes that the hydraulic
12 conductivity of this unit..."

13 being the highly fractured shale as defined by Trow:

14 "...does not exceed 1×10^{-5} cm/sec."

15 based on the pressure packer test data. That statement
16 is consistent if you used the slug test data which
17 showed values even lower or more strongly negative than
18 10^{-5} .

19 Q. Could you correct that sentence
20 for us, the last sentence in, I guess, the second
21 paragraph on the page. How should it read?

22 A. "It should be noted that
23 reasonable agreement is not achieved
24 where similar sections of a borehole
25 were tested by both procedures."



1 DR. KINGHAM: While we are making that
2 correction, when you say slug test can we equate that
3 to the Hvorslev test?

4 MR. PETRIE: Hvorslev was the man who
5 developed the mathematics that were in this case used
6 by Trow but slug is the field procedure and I am using
7 them synonymously, yes.

8 MR. McQUAID: Q. Could I ask you to
9 pick up after the comment in the third paragraph on
10 page 38 where you make reference to the 13 values for
11 hydraulic conductivity of the weakly fractured shale.
12 Are those the values we have been looking at on what is
13 page 37, the figure that is page 37?

14 MR. PETRIE: A. Those are some of the
15 values. This argument I believe was developed from
16 Ms. Vigod cross-examining Mr. Feenstra when she asked
17 him to go through Appendix 11 of the Trow data, being
18 all the available hydraulic conductivity data. In
19 going through that the values that were representative
20 of the weakly fractured shale as defined by Trow as
21 being hydrostratigraphic unit 3, there were 13 values
22 in that appendix for that rock unit.

23 In going through those data it became
24 apparent that Trow had reported a value for zero for
25 hydraulic conductivity where, during the pressure



1 packer tests, essentially no water was taken up by the
2 rock and it transpired that a value of zero would be
3 appropriately enumerated as a value of 1×10^{-8}
4 centimetres per second and from that data Mr. Feenstra
5 calculated a geometric mean, from that data being the
6 13 values for the hydraulic conductivity for unit 3, a
7 geometric mean of a value of 6.3×10^{-7} was calculated.

8 I believe that that was on an exhibit --
9 oh, I beg your pardon, at the bottom of page 38 I
10 reference H-262. That exhibit contains the 13 values
11 identified Mr. Feenstra as lying within the weakly
12 fractured shale as he interpreted the data from Trow's
13 report and this geometric mean I believe is also
14 provided on that exhibit. The geometric mean being
15 6.3×10^{-7} .

16 Q. You indicate that that value
17 contrasts with the 10^{-7} to 10^{-8} centimetres per second
18 that Trow indicated was the hydraulic conductivity of
19 the unit?

20 A. Yes, I do. On Exhibit B-516 we
21 have the weakly fractured shale being unit 2 and it has
22 -- I beg your pardon, the weakly fractured massive
23 shale being unit 3 -- and it has a value indicated here
24 of a hydraulic conductivity of 1×10^{-7} centimetres per
25 second.



1 Q. All right.

2 A. On page 51 of Exhibit H-40, and I
3 am referencing the figure heading of 6.2.3 being the
4 weakly fractured massive shale unit on page 51, the
5 fifth line down, and that indicates they have low
6 values of 10^{-7} to 10^{-8} centimetres per second for this
7 unit. In addition, if I can back up, in model A, the
8 first model provided by Trow, a value of 1×10^{-7} was
9 entered as the hydraulic conductivity for unit 3 and in
10 the second model which I referred to as model B, the
11 value was 1×10^{-8} , but let me point out the
12 difference. The 1×10^{-7} was using an isotropic system
13 in which the horizontal and vertical hydraulic
14 conductivity are exactly the same.

15 For model B a degree of anisotropy was
16 introduced into the system in which the horizontal
17 hydraulic conductivity was kept as 1×10^{-7} and the
18 vertical hydraulic conductivity was a factor of 10
19 times smaller, i.e., 1×10^{-8} . Using that range of
20 numbers, that would indicate that the value assigned by
21 Trow, assigned in their computer modeling, is 6 to
22 perhaps as much as 60 times lower than the mean value
23 determined from the field tests. Essentially the field
24 test data show a value of 6.3×10^{-7} and Trow modelled
25 a value of 1×10^{-7} .



1 Q. You continue to discuss the
2 hydraulic conductivity values for unit 3 in the next
3 paragraph on page 39 and make a comment on the use of
4 the .3 metre interval by Trow?

5 A. Correct. At HC4, being the
6 borehole on the left side of the figure before you, we
7 have over this interval, and this is enumerated in the
8 text as being 111.9 to 122.2 metres in the first
9 complete paragraph on page 39, and over that 3.1
10 vertical metres we have an assigned hydraulic
11 conductivity -- I beg your pardon, I think I am looking
12 at the wrong number.

13 No, it is correct. 119.1 to 122.2. I
14 am looking at the lowermost of the pressure packer test
15 data on HC4, the lowermost one has a value of 1.6×10^{-5}
16 and I just would make a note here that if the whole
17 of that 3 metre zone was equally fractured, then the
18 1.6×10^{-5} would be representative of that complete
19 vertical interval. If only a portion of that rock were
20 more fractured than the remaining portions of the rock,
21 then we could expect a different hydraulic
22 conductivity.

23 For example, if that 3 metres of rock
24 contained a .3 metre zone which was fractured and we
25 did our pressure packer test over the full vertical



1 interval, we may expect that the hydraulic conductivity
2 applied to the .3 metre zone instead of the 3 metre
3 zone would yield a result of 1.6×10^{-4} . All I have
4 done there is say instead of applying the hydraulic
5 results from testing over a 3 metre zone, apply them
6 over a .3 metre zone and what would the result be? The
7 result would be an order of magnitude higher in the
8 calculated hydraulic conductivity for that portion of
9 the rock.

10 Q. What would you as a hydrogeologist
11 calculate it over?

12 A. I would take it over the test
13 interval. However, the point I wish to relate is that
14 referring back to the fracture frequency diagrams I had
15 up earlier, and I am referring back to Figure B.2.2,
16 being page 23 of our report, we are looking in a small
17 zone in this vertical interval, this vertical interval
18 being -- can I try and overlay these two figures
19 exactly on each other? I think it is easier if I
20 don't.

21 What I am indicating at this point is
22 that over this interval which was pressure packer
23 tested we have a zone which is significantly more
24 fractured than the adjacent rock mass. I arbitrarily
25 assigned a vertical thickness of .3 and said that were



1 that .3 metres taking up the water that was lost during
2 the pressure packer tests, I might have calculated a
3 value of 1×10^{-4} -- 1.6×10^{-4} for the hydraulic
4 conductivity of that zone rather than applying the
5 value over a 3 metre interval for which I have variable
6 fracture densities within the rock.

7 Q. What does this focusing on unit 3
8 and these various hydraulic conductivities indicate to
9 you?

10 A. The unit 3 is the lowest permeable
11 rock mass as defined by Trow within the sequence at
12 this site. Were this unit 3 continuous and on the
13 hydraulic conductivity they have assigned, it would
14 lead me to a set of conclusions regarding the pattern
15 of groundwater flow, the rate of groundwater flow at
16 this site. Based on the hydraulic conductivity data I
17 have available to me and the water level data available
18 to me, I do not see that the weakly fractured shale
19 exists as defined and I find as I come to part C in
20 this report and provide our conceptualization of this
21 site, I cannot interpret that data readily regarding
22 groundwater flow directions and groundwater flow rates
23 within the fractured rock at this site.

24 Q. You make a comment on page 39 that
25 the data demonstrates that hydraulic conductivities in



1 this unit 3 can range over 4 orders of magnitude, from
2 10^{-8} for the more massive rock to 10^{-4} centimetres per
3 second for discrete fractures zones?

4 A. Correct, and that range of numbers
5 tells me that hydrogeologically that portion of the
6 site defined by Trow as hydrostratigraphic unit 3 is a
7 heterogeneous rock mass and not readily characterized
8 by any one value of hydraulic conductivity. It has a
9 variable amount of fracturing in it such that we have
10 portions of rock with low hydraulic conductivity,
11 portions of rock with significantly higher hydraulic
12 conductivity and I cannot define that zone as defined
13 based on this hydraulic conductivity data.

14 Q. Continuing quickly at the bottom
15 of page 39 you make a comment with respect to unit 2 at
16 HC4?

17 A. Correct. Unit 2 is defined by
18 Trow as the uppermost unit of rock and it is identified
19 as the moderately fractured and weathered shale. The
20 highest hydraulic conductivities we encountered at this
21 site, I recall, are at HC4, and were encountered within
22 this unit. We had similar values encountered at HC3
23 which is essentially through the cross-section from HC4
24 and at approximately the same relative elevation. We
25 had similar values. A value of 10^{-3} exceeds the value



1 of the hydraulic conductivity presented by Trow on
2 their summary of hydrostratigraphic units and the value
3 presented here for unit 2 is 1×10^{-5} .

4 Again, we have a heterogeneous unit in
5 which there are high hydraulic conductivities and lower
6 hydraulic conductivity values measured. We again are
7 dealing with a fractured rock mass in which those
8 fractures which provide for the movement of groundwater
9 have been expected to have higher hydraulic
10 conductivities and those fractures which provide for
11 lesser movement or perhaps which are isolated and which
12 are not interconnected in any fashion provide for a
13 lower measured hydraulic conductivity.

14 Q. Could I refer you to the last
15 paragraph in this section in the middle of page 40:

16 "The moderately fractured and weathered
17 shale (Unit 2) has hydraulic
18 conductivity values that range up to
19 10^{-3} cm/sec which is two orders of
20 magnitude in excess of the 10^{-5} cm/sec
21 determined by Trow for this unit..."

22 And is that the point you are just making?

23 A. Correct, and I reference the
24 10^{-5} on B-516 and the high values for hydraulic
25 conductivity I see defined by the pressure packer test



1 at HC4 on Figure B.3.6.

2 Q. Just going two paragraphs above
3 that last paragraph beginning with the third last one:

4 "CRA concludes that the available
5 hydraulic conductivity data do not
6 support..."

7 and then you go on to make a comment about the
8 existence of the highly fractured shale unit No. 4 with
9 a hydraulic conductivity of 1×10^{-2} centimetres per
10 second and that it cannot be supported. You commented
11 on that at 10^{-3} and 10^{-4} also?

12 A. Correct. I cannot support 10^{-3} or
13 a value of 10^{-4} based on the hydraulic conductivity
14 data available. The available data leads me to
15 conclude that that portion of the rock defined by Trow
16 as highly fractured shale, that portion being indicated
17 on B.3.6 generally below an elevation of 110 metres,
18 would have a hydraulic conductivity of the order of
19 1×10^{-5} at the high end.

20 Q. In the middle paragraph of those 3
21 on page 40 I think you have commented on the four order
22 of magnitude range in unit 3 back on page 39, and
23 that's the same point you made earlier?

24 A. That is correct.

25 Q. So, looking at this section again



1 and just to conclude, having looked at the hydraulic
2 conductivities, and relating those back to the model or
3 I guess the model schematic hydrostratigraphy we see on
4 B-516, could you summarize your conclusions having done
5 that, or having focused on the hydraulic
6 conductivities?

7 A. Focusing on the hydraulic
8 conductivities I cannot agree with the site definition
9 as postulated by Trow, the site definition being
10 summarized on B-516 which provides a summary of the
11 hydrostratigraphic units. With reference to the data
12 we have just addressed, I see values in Trow's highly
13 fractured shale were it to exist as defined in the
14 order of 10^{-5} and I see values within the weakly
15 fractured massive shale being unit 3 that range up to
16 10^{-5} . I see values in the moderately fractured shale
17 that range up to 10^{-3} .

18 In summary, I see a significant range in
19 values for the hydraulic conductivity at this site in
20 and in an attempt to correlate high values laterally
21 across the site, or vertically with any one borehole, I
22 can conclude that this site cannot be differentiated
23 into the hydrostratigraphic units we see defined before
24 us on B-516.

25 DR. KINGHAM: I know we are anxious to



1 get on the road, but there is something I would like to
2 think about overnight and maybe you could help me with
3 it, and it was triggered by a comment you made having
4 regard to the anisotropic conductivity, and I think you
5 said it was an order of magnitude less horizontally
6 than vertically. Did I get that right?

7 MR. PETRIE: I can repeat my statement.
8 Trow in their second model, model B, introduced a
9 degree of anisotropy in which the horizontal hydraulic
10 conductivity is ten times higher than the vertical or
11 ten times faster, or with reference to a number here,
12 if it was 7.2×10^{-7} in the horizontal, it would be
13 7.2×10^{-8} in the vertical. I should point out that
14 all the values you see before you are representative I
15 believe of horizontal hydraulic conductivities and they
16 are test methods which introduce water or pressurize
17 the system where stresses are moved out laterally from
18 the borehole and none of the test procedures in my mind
19 give a meaningful measure of vertical hydraulic
20 conductivities of the procedures we see here.

21 DR. KINGHAM: Thank you.

22 MR. McQUAID: This would be a convenient
23 point to break, sir.

24 MR. LANCASTER: Very well. Nine-thirty
25 tomorrow.

---Adjournment at 4:40 p.m.



Nethercut & Co. Ltd.

Toronto, Ontario

25344

Crutcher, Petrie
ex (McQuaid)

1

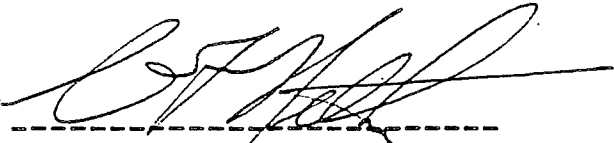
2

Certified Correct

3

4

5



C. F. Nethercut, C.V.R.

6

7

(Page No. 25400 follows)

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25