StatoilHydro

September 23, 2009

ALBERTA ENERGY RESOURCES CONSERVATION BOARD
640 – 5th Avenue S.W.
Calgary, AB T2P 3G4

Attention: **Mr. Ken Schuldhaus, P.Eng.**

RE: Supplemental Information Request (3) for ERCB Application No. 1523635 (the Application); EPEA Application No. 001-241311; Water Act File No. 00239880
Kai Kos Dehseh Project – Athabasca Oil Sands Area

In support of the Application, StatoilHydro Canada Ltd. (StatoilHydro) has completed the responses to the Supplemental Information Request (SIR (3)), dated July 15, 2009, for the Kai Kos Dehseh Project (the Project).

North American Oil Sands Corporation (North American), now StatoilHydro Canada Ltd. (by way of amalgamation) had applied to the Energy Resources Conservation Board (ERCB) and Alberta Environment (AENV) for approval to construct and operate the Kai Kos Dehseh In-Situ Oil Sands Project. StatoilHydro has assumed North American's role as the Application's proponent.

As outlined in the Application, the Project involves four development areas: Leismer, Corner, Thornbury and Hangingstone and the Application addresses StatoilHydro's overall development plan for the Project. The Project development plan is based on the Leismer and Corner development areas being developed first followed by the other two development areas. With this in mind, and with respect to the Project Environmental Impact Assessment (EIA), StatoilHydro wishes to again highlight the EIA's unique nature. To facilitate more openness and transparency of the overall Project development plan in the local communities, StatoilHydro has completed a broader regional EIA that fully outlines the proposed commercial development plan for the overall Project within the approximately 12 townships of oil sands leases now held by StatoilHydro.

This regional EIA approach was developed in full consultation with various regulatory agencies, including the ERCB, AENV and Alberta Sustainable Resource Development (ASRD). Support in principle was received and as result it was agreed that StatoilHydro would apply for overall Project approval based on one regional EIA. To the extent that detailed information for each development area was required, that information would be included, as applicable, in either the Application or any future amendment applications (instead of using separate stand-alone EIAs for each development area).

StatoilHydro believes this regional EIA approach has provided the stakeholders with transparency of its planned implementation for overall Project development and this transparency is in the public interest. The EIA is based on regional data and a conceptual engineering and execution plan. Several of the EIA programs, such as some of the wildlife baseline studies (caribou, moose and wolf), were tailored with feedback from local stakeholders to address their specific interests.

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As overall Project development progresses, subsequent approval amendment applications for each of the Thornbury and Hangingstone development areas will be submitted. StatoilHydro acknowledges that if significant changes in the region occur, AENV may request additional environmental studies to supplement the existing EIA. All future amendment applications will contain the required level of information for each applicable development area and will be based on the acquisition of additional geological, reservoir and engineering information.

With the submission of these responses to the SIR(3) combined with the EIA and the responses to the Round 1 of the SIRs, dated July 23, 2008, as well as Round 2 of the SIRs, dated February 4, 2009, StatoilHydro is of the position that the Terms-of-Reference for this EIA have been met. StatoilHydro looks forward to the ERCB's and AENV's decision on the completeness of both the Kai Kos Dehseh Project Application (Volume 1) and the accompanying Environmental Impact Assessment (Volumes 2 – 5).

We trust that you will find the attached responses to your information requests in order.

Yours truly.

STATOILHYDRO CANADA LTD.

Lorne Cannon, P.Eng.
Vice President, Leismer Asset

cc:
Laura Hickman – ERCB
Corinne Kristensen – AENV
Craig Popoff, P.Eng – Director, Regulatory & HSE, StatoilHydro Canada Ltd.

StatoilHydro

Title:

APPLICATION FOR APPROVAL OF
KAI KOS DEHSEH PROJECT
SUPPLEMENTAL INFORMATION REQUEST ROUND 3

Date:

SEPTEMBER 2009

Submitted to:

ALBERTA ENVIRONMENT
AND ENERGY RESOURCES CONSERVATION BOARD

Submitted by:

StatoilHydro Canada Ltd.

September 23, 2009

ALBERTA ENERGY RESOURCES CONSERVATION BOARD
640 – 5th Avenue S.W.
Calgary, Alberta T2P 3G4

Attention: Laura Hickman

RE: **Supplemental Information Request (3)**
Kai Kos Dehseh Project – Athabasca Oil Sands Area
ERCB Application No. 1523635
EPEA Application No. 001-241311
Water Act File No. 00239880

TECHNICAL REVIEW

A. GENERAL
1) Volume 1, Page 1 and Figure 1-2, Page 4.
StatoilHydro states, "*Each hub is comprised of a central processing facility (CPF) (which may include steam generation, water treatment, emulsion gathering and treating, and sulphur removal) and field facilities (which includes well pads, connecting roads and utilities).*"

Similar language exists throughout the application and SIR responses where "hub" is stated to refer to a CPF and field facilities. However, Figure 1-2 and similar figures presented have included a label in the legend which appears to show "hubs" separately and not including associated well pads or "footprint infrastructure".

> **a. Amend Figure 2-1 and similar figures as necessary to indicate the proposed central processing facility locations of the Leismer Commercial Hub, Leismer Expansion Hub and Leismer Corner Hub, individually. These figures should include a section and township grid, indicate the applied for development area boundary, the applied for project area boundary and depict the applied for pad and wellbore layouts. Note that the project area should deal specifically with StatoilHydro's future planned development, within the scope of the area targeted by the environmental impact assessment, and should be explicit in the inclusion/exclusion of any joint venture leases.**

RESPONSE

StatoilHydro continues to define a "Hub" as a central processing facility (CPF) (which may include steam generation, water treatment, emulsion gathering and treating, and sulphur removal) and field facilities (including well pads, connecting roads and utilities).

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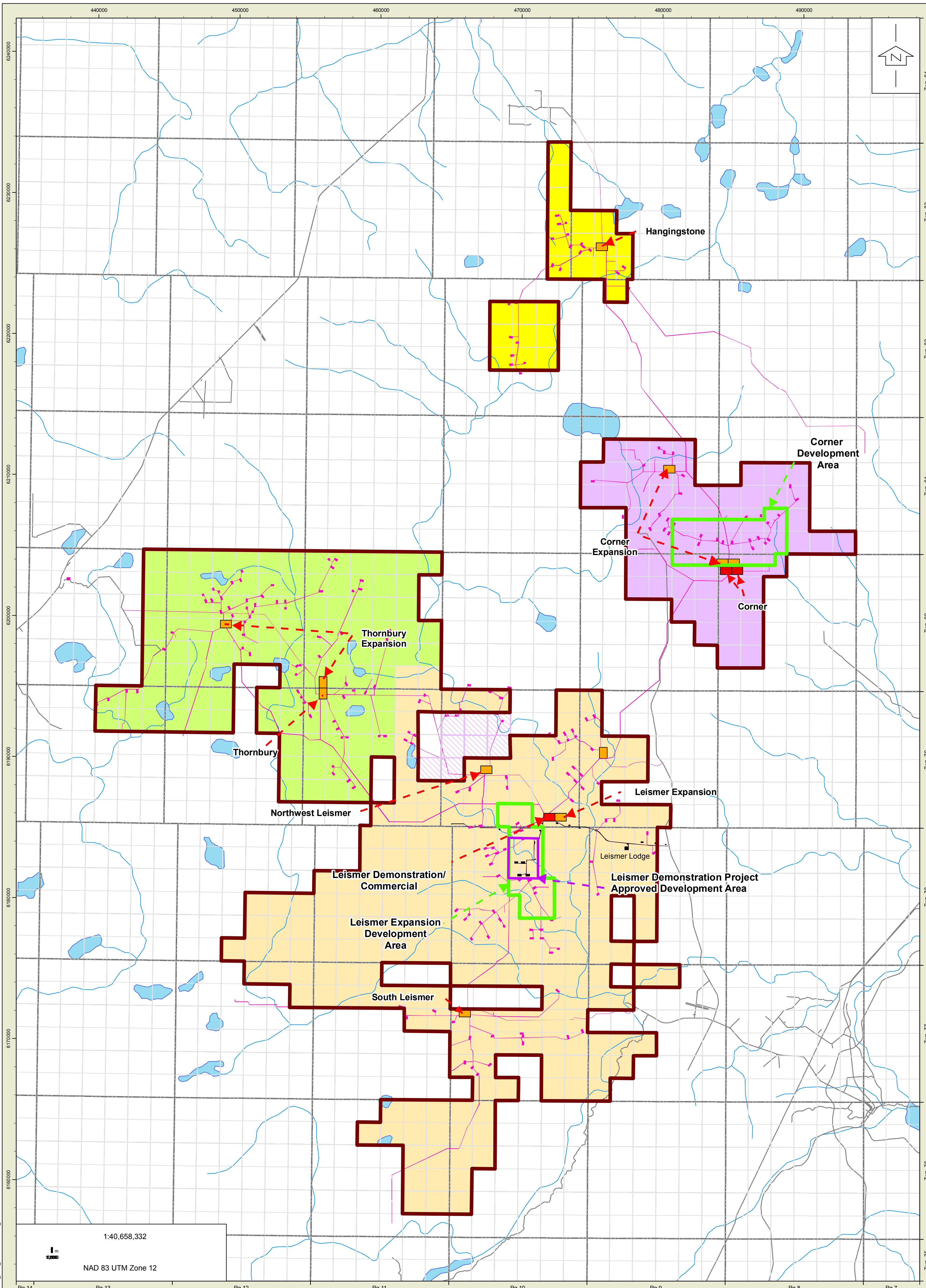
To improve clarity, Figures 1-2 and 4.1-1 (EIA, Volume 1) of the Application have been amended as Figures 1-1 and 1-2, respectively, to indicate the central processing facility (CPF) locations contained within, or adjacent to, the proposed Leismer Commercial/Expansion Development Area and proposed Corner Development Area. Future CPFs or other production facilities are also noted within the proposed broader Kai Kos Dehseh (KKD) Project Area. The Project Area is within the area assessed in the Environmental Impact Assessment. These updated figures also include a depiction of the applied for KKD Project Area, proposed initial Development Areas (Leismer and Corner) and well pad locations.

The cross-hatched area on the Figures 1-1 and 1-2 indicate two small parcels of land consisting of a total of eight sections, which are partnered with Nexen Inc. and/or Imperial Oil Limited. StatoilHydro indicated in Section 2.3 (EIA, Volume 1), page 13, that "North American (now StatoilHydro) has not entered into formal agreements with Nexen and/or Imperial Oil and, as such, is not proposing any development, at this time, on these jointly-held lands."

The circumstances relating to these jointly-held lands have not changed. At this time, StatoilHydro does not intend to include these jointly-held lands for the purposes of the Application, and the Figures 1-1 and 1-2 have been modified to indicate this more clearly. Should StatoilHydro successfully enter into formal operating agreements with its partners relating to these lands, an application may be made at that time to amend the current approval for the KKD Project to include these lands. The potential bitumen resources under these joint-venture lands were not used to calculate the production forecasts in the KKD Project Application, so this change will not affect these forecasts or the estimates of the overall productive capacity of the Project.

Both Figures 1-1 and 1-2 indicate the footprint infrastructure of the KKD Project, which includes proposed well pad areas in pink. It has been noted in conversations with ERCB staff that a few of these well pads (such as two on the southern edge of Township 80, Range 10) are placed slightly outside of the proposed KKD Project Area. These well pads have been placed so that the horizontal wellbores can be located beneath StatoilHydro's bitumen leases to maximize the exploitation of the oil sands resource based on current information. The bitumen resource in these areas will be further defined by a higher density of oil sand evaluation (OSE) wells and the location of these proposed well pads may change. The placement of these well pads would be a potential surface rights issue (to be resolved later) because the operating portions of the SAGD horizontal wellbores would actually be located under StatoilHydro's bitumen leases.

Two new maps have been created at a 1:20,000 scale (Figures 1-3 and 1-4) to facilitate more effective evaluation of the proposed Leismer Commercial/Leismer Expansion and the Corner Development Areas. Figure 1-3 also depicts the currently approved Development Area (as per Approval No. 10935C) for the Leismer Demonstration Project (LDP), which is also the proposed Development Area for Leismer Commercial. Both Figures 1-3 and 1-4 indicate OSE well density, 3D seismic coverage, as well as proposed well pads and wellbore layouts.



Legend

- Kai Kos Dehseh Project Area/ Lease Boundary
- ATS Township / Range
- Roads
- Lake
- Stream
- CPF
- Future CPF or other Production Facility
- Footprint Infrastructure
- Joint Venture Lands
- Development Area
- Leismer Lease Boundary
- Corner Lease Boundary
- Hangingstone Lease Boundary
- Thornbury Lease Boundary
- Leismer Demonstration Project Approved Development Area
- Wellpad

Title:

KAI KOS DEHSEH PROJECT AREA AND DEVELOPMENT AREAS

StatoilHydro

Approved: RS	Revision Date: Aug. 7, 2009
File: Figure 1-1_PROJECT_AND_DEVELOPMENT_AREAS.mxd	

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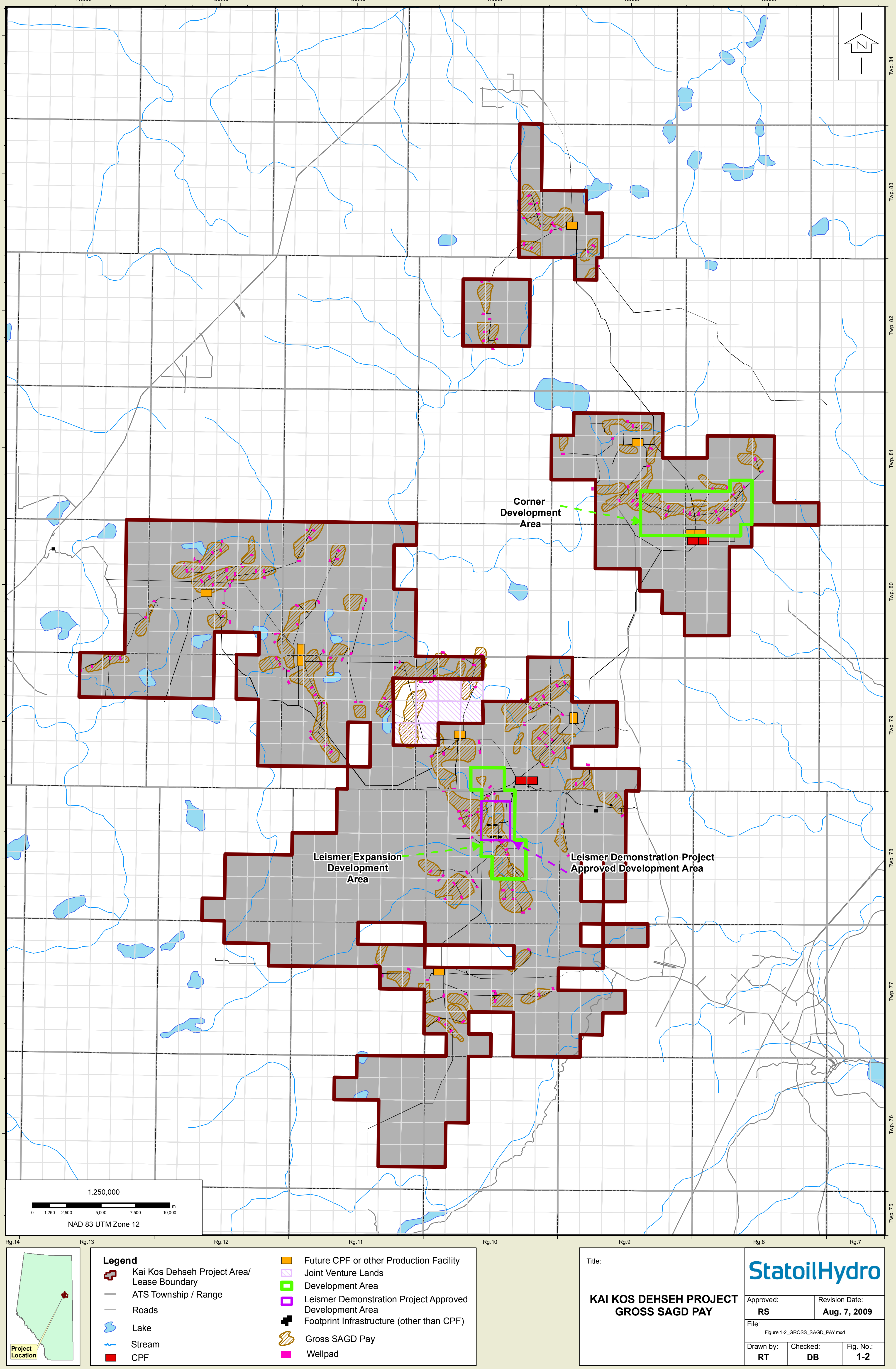

Title:

KAI KOS DEHSEH PROJECT GROSS SAGD PAY

StatoilHydro

Approved:	Revision Date:
RS	Aug. 7, 2009

File: Figure 1-2_GROSS_SAGD_PAY.mxd

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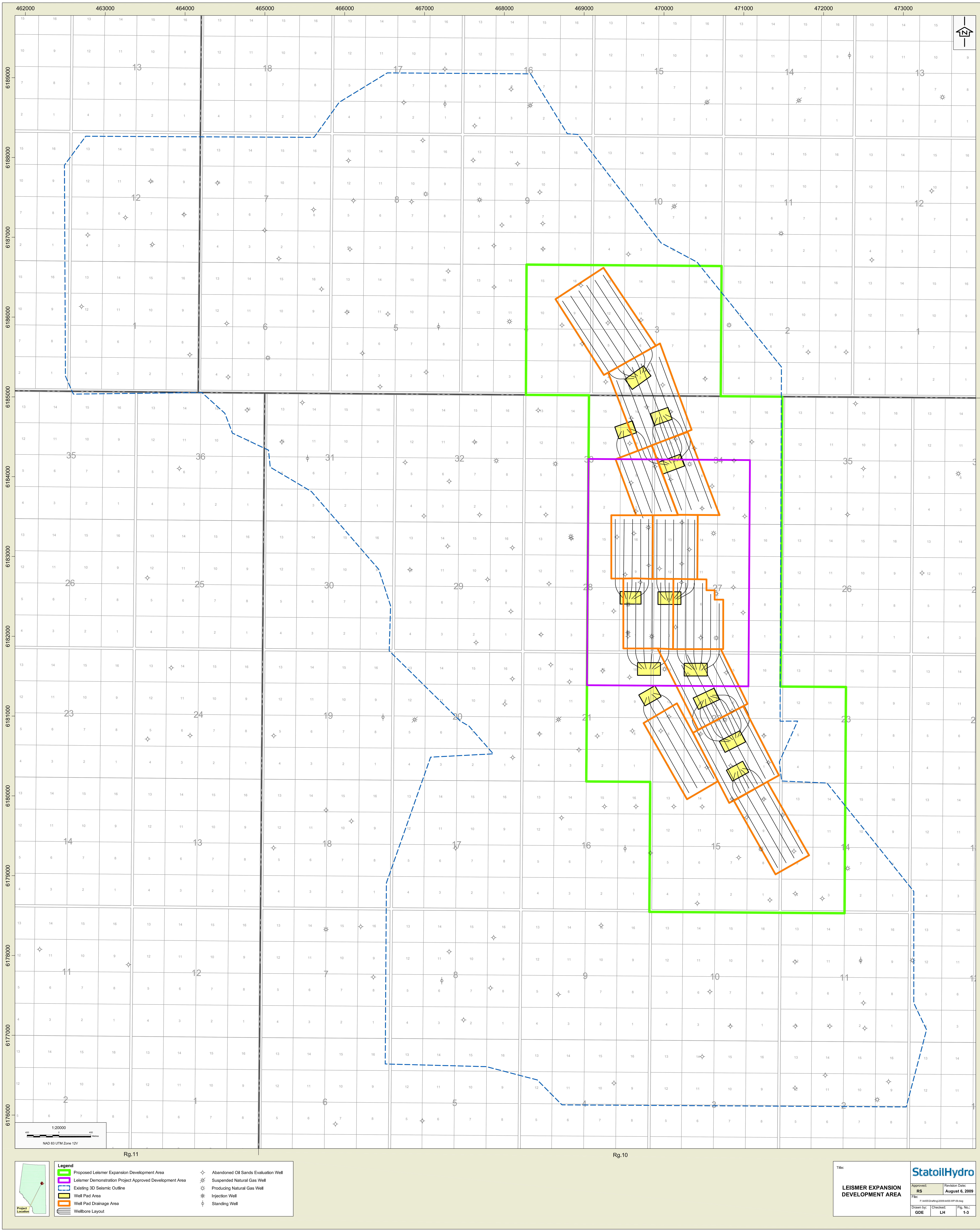

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Project Location
Legend
Proposed Leismer Expansion Development Area
Leismer Demonstration Project Approved Development Area
Existing 3D Seismic Outline
Well Pad Area
Well Pad Drainage Area
Wellbore Layout
Abandoned Oil Sands Evaluation Well
Suspended Natural Gas Well
Producing Natural Gas Well
Injection Well
Standing Well
Title:
LEISMER EXPANSION DEVELOPMENT AREA
StatoilHydro
Approved: RS
Revision Date: August 6, 2009
File: F:\4455\Drafting\2009\4455-WP-09.dwg
Drawn by: GDE
Checked: LH
Fig. No.: 1-3

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NAD 83 UTM Zone 12V
Project Location
Legend
Proposed Development Area
Existing 3D Seismic Outline (2006 - 2008 vintage)
Well Pad Area
Well Pad Drainage Area
Wellbore Layout
Kia Kos Dehseh Project Area / Lease Boundary
Abandoned Oil Sands Evaluation Well
Suspended Natural Gas Well
Producing Natural Gas Well
Injection Well
Location Well
Water Well
Title:
CORNER DEVELOPMENT AREA
StatoilHydro
Approved: RS
Revision Date: August 6, 2009
File: F:\4455\Drafting\2009\4455-WP-09.dwg
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Fig. No.: 1-4

2) **Volume 1, Page A-1; Page A-18.**
StatoilHydro states (regarding the application for the Leismer Commercial Hub), "*The increase in production for the Leismer Commercial Hub will not require any additional well pads, CPF area or steam generating equipment*", followed by, "…(StatoilHydro) *hereby applies for regulatory approval to amend, construct, operate and reclaim the proposed Leismer Commercial Hub…The CPF for the Leismer Commercial Hub will be located in the SE 1/4 of 2 in 79-10 W4M.*"

> **a. ERCB Approval No. 10935B for StatoilHydro's Leismer Demonstration Project illustrates surface facilities located in LSDs 7 to 10 within 02-079-10W4M. The above statement appears to contemplate a CPF area within LSDs 1, 2, 7 and 8 of Section 2. Clarify this apparent discrepancy.**

RESPONSE

The increase in production associated with the Leismer Commercial Hub will not require any additional well pads, CPF area or steam generating equipment. However, there does appear to be a discrepancy between the legal land description provided on page A-18, and the location of surface facilities given in ERCB Approval No. 10935B. StatoilHydro wishes to confirm that the Leismer Commercial CPF will be located within the footprint depicted in Approval Nos. 10935B and 10935C, and that this footprint represents the most current approved location of the CPF.

B. SOURCE AND DISPOSAL WATER
3) **Volume 1, Page 1; SIR (1) 30, Page 65; Volume 1, Section B4.3.7, Page B-86 Hydrogeologic Evaluation; Volume 1, Table 4.4-1, Page 81.**
StatoilHydro states, "*Each hub is comprised of a central processing facility (CPF) (which may include steam generation, water treatment, emulsion gathering and treating, and sulphur removal) and field facilities (which includes well pads, connecting roads and utilities).*" StatoilHydro also states in response to SIR (1) 30 that its "*objective is to maximize the integration of the Leismer Demonstration/Commercial/Expansion facilities and operate all sections as a single plant.*"

On Page B-86 of Volume 1 of the application relating to the Leismer Expansion Hub, StatoilHydro states, "*the water demands and supporting aquifers for the Leismer Hub are 1,960 m3/d from the Lower Grand Rapids Aquifer and 1,900 m3/d from the Basal McMurray Aquifer*", yet Table 4.4-1 on Page 81 of the application shows the long term make-up requirements of the Leismer Expansion as 1930 m3/d.
From the materials provided, it is unclear as to whether production associated with the Leismer Expansion hub will require 1930 m3/d or 3860 m3/d of make-up water.

> **a. Clarify this apparent discrepancy. Also, clarify which of the quoted figures refer to the overall Leismer development as a whole and which refer to a specific 'hub', or phase, of the development.**

RESPONSE

In the above cited places in the Application, the term "Leismer Hub" is used incorrectly. What was intended was a reference to the overall Leismer development as a whole.

Table 4.4-1 on Page 81 (EIA, Volume 1) presents the water source requirements for the individual hubs of the overall Leismer development. The separate make-up water needs of the Leismer Commercial Hub and the Leismer Expansion Hub are presented on two separate rows, which total 1,930 m^3/d each, so the overall Leismer development make-up water requirements are 3,860 m^3/d. This is confirmed by the

Hydrogeologic Evaluation in Appendix B, Section B4.3.7, page B-86 (EIA, Volume 1), which indicates the water demands for the overall Leismer development as 1,960 m^3/d from the Lower Grand Rapids Aquifer and 1,900 m^3/d from the Basal McMurray Aquifer, for a total of 3,860 m^3/d.

C. RESERVOIR AND PRODUCTION

4) **Volume 1, Section B4.2.2.3, Page B-83, Reservoir Surveillance; Volume 1, C4.2.2.3, Page C-81, Reservoir Surveillance ; SIR(1) 3a and b, Page 18; SIR(1) 3e, Page 25. StatoilHydro states, "…*the target average operating pressure for long term SAGD depletion*" is 2500 kPa for both the Leismer Expansion and Leismer Corner hubs (Pages B-83 and C-81). In response to SIR(1) 3a and b, StatoilHydro has stated that the maximum bottomhole circulation pressure during start-up and maximum steam chamber pressure proposed for each of the hubs is 6000kPa. StatoilHydro further states, "*Due to the possibility of thief zones, and late-life heat management of the SAGD process, it is likely the operating pressure will be lower than the maximum during much of the life of a well pair.*" StatoilHydro has previously responded to SIR(1) 3b, stating that the maximum bottomhole circulation pressure during start-up operations is 6000 kPa. Further clarification and precision regarding the proposed start-up, steam chamber and operating pressures are required.**

a. What is the optimum bottomhole circulation pressure during start-up operations?

RESPONSE

Across the KKD Project Area, there is significant variation in McMurray reservoir quality and characteristics. It would not be possible to identify a particular optimum bottomhole circulation pressure during start-up opertions for the entire KKD Project Area because any determination of an "optimum" pressure would depend upon local reservoir conditions, such as original reservoir pressure, formation heterogeneity, presence and severity of any thief zones; as well as the design of the production facilities, the features of the lift system and the well completion strategy.

The target start-up circulation pressure for the KKD Project Area will likely vary from 2,500 - 5,000 kPa. This target range may be revised up or down slightly, as individual cases may require, to raise the steam temperature of the horizontal well toes in a safe and efficient manner. The 6,000 kPa level described in SIR(1) #3(b) refers to the upper pressure limit for facility considerations and potential maximum steam chamber pressure that could be encountered.

b. Outline the conditions (why and when) under which the stated maximum injection pressure of 6000 kPa would be operationalized.

RESPONSE

The targeted steady-state SAGD operating steam chamber pressure range for the KKD Project Area has been indicated in the response to SIR(3) #4(a) above. For the purposes of SAGD recovery optimization at Corner, StatoilHydro recognizes the need to maintain operational flexibility, and this may involve increasing the injection pressure to a higher range for short periods from time-to-time up to, but likely not exceeding, the 6,000 kPa level.

The potential scenarios where such temporary high-pressure operating options may be investigated at Corner.

i) If there were a localized low-permeability zone around the injector, this would reduce reservoir steam intake and hamper steam chamber initialization following the transition from a circulation phase to a SAGD operating mode. A temporarily higher operating pressure could facilitate more rapid steam break-out of local low-permeability zones, and therefore normalize SAGD steam chamber development.

ii) Localized Inclined Hetrogeneous Strata (IHS) or low-permeability baffles separating the injector and the producer could hamper normal drainage development. A temporary high-pressure operation could reduce the time for establishing normal SAGD flow behavior.

iii) Oilsands dilation and any resulting permeability enhancement effects may be more pronounced at higher steam chamber pressures. A 6,000 kPa pressure maximum would permit investigation and formulation of such recovery enhancing strategies, when warranted.

c. Discuss and/or illustrate how long StatoilHydro anticipates it would take to reduce the bottomhole steam chamber pressure from 6000 kPa to the proposed normal operating pressure of 2500 kPa.

RESPONSE

Any high-pressure technique implemented in the Corner Project Area would only be used on a short-term basis (in the order of weeks) to facilitate normal steam chamber development. The duration of these operations would depend upon the severity of the IHS, and/or baffles at a particular subsurface location. If utilized, the high-pressure techniques would be undertaken over enough time to establish whether this operating strategy had in fact enhanced steam chamber development.

The time period for returning the reservoir to 2,500 kPa pressure from 6,000 kPa would depend upon the reservoir permeability, the maturity and physical extent of the steam chamber at the time, the duration and steam pressurization volume used, risk of sanding, and the subsequent rate of drawdown applied at the producer.

To ensure caprock integrity and avoid potentially undesirable steam channeling to adjacent wells, StatoilHydro will monitor the pressure, temperature, flow rates, and sensor readings from adjacent observation and other SAGD wells for the complete duration of any high-pressure operation conducted.

d. In response to SIR(1) 3e, StatoilHydro indicates that hydraulic fracturing stress tests were conducted at two Leismer Hub area wells. Provide the stress test report(s).

RESPONSE

Two hydraulic fracturing stress test reports are attached as Appendix I and Appendix II.

5) Volume 1, Figure 2.4-1, Page 20.
Figure 2.4-1 shows that the Leismer Commercial Hub will maintain a plateau rate of 20 000 bpd for about 25 years. Provide the following:

a. Tabulate or graph the single type well-pair performance prediction for the Leismer Commercial Hub, showing bitumen rate, steam rate, instantaneous steam oil ratio (ISOR) and recovery factor from start up to the end of the well pair's life, using the criteria proposed by StatoilHydro.

RESPONSE

The following Figures 5-1 and 5-2 represent graphs of a typical well profile for the Leismer Commercial Hub:

Figure 5-1

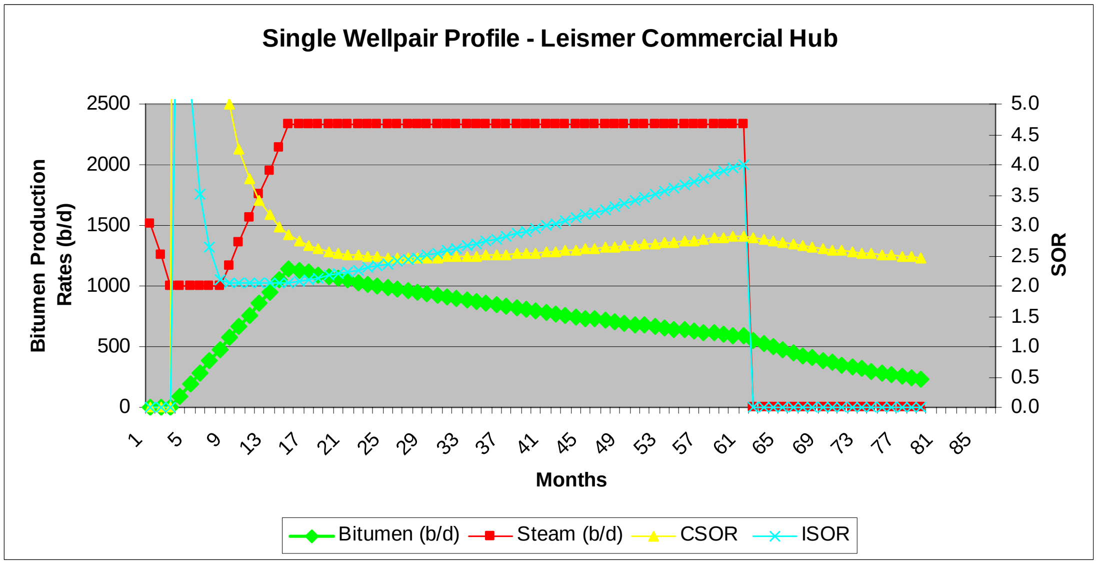
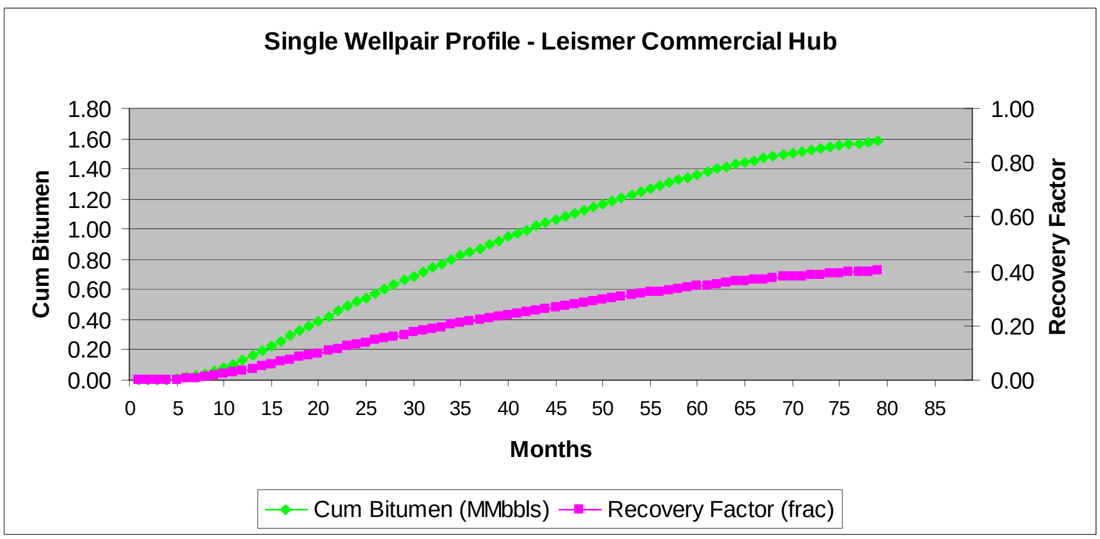


Figure 5.2

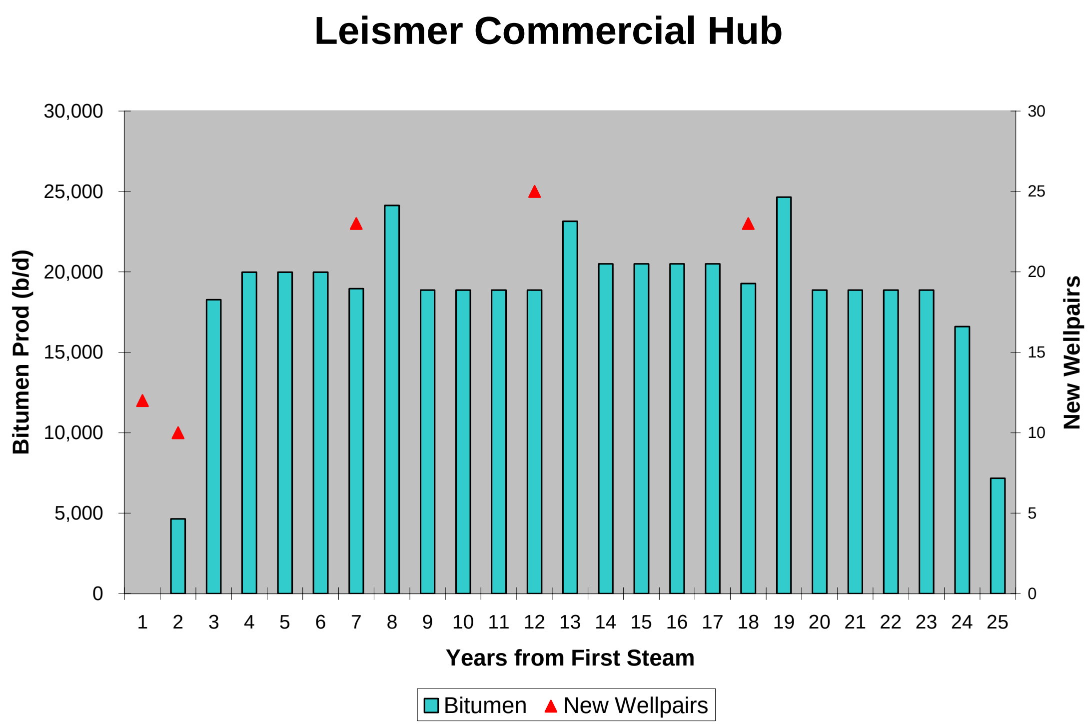


b. Develop a field (production) forecast for the Leismer Commercial Hub with the necessary number of future well pairs to be brought on for production at each phase to sustain the plateau rate of 20 000 bpd for 25 years.

<u>RESPONSE</u>

The following graph in Figure 5-3 shows the production forecast for the Leismer Commerial Hub, as well as indicating the number of new well pairs required to produce 20,000 bpd for 25 years.

Figure 5-3



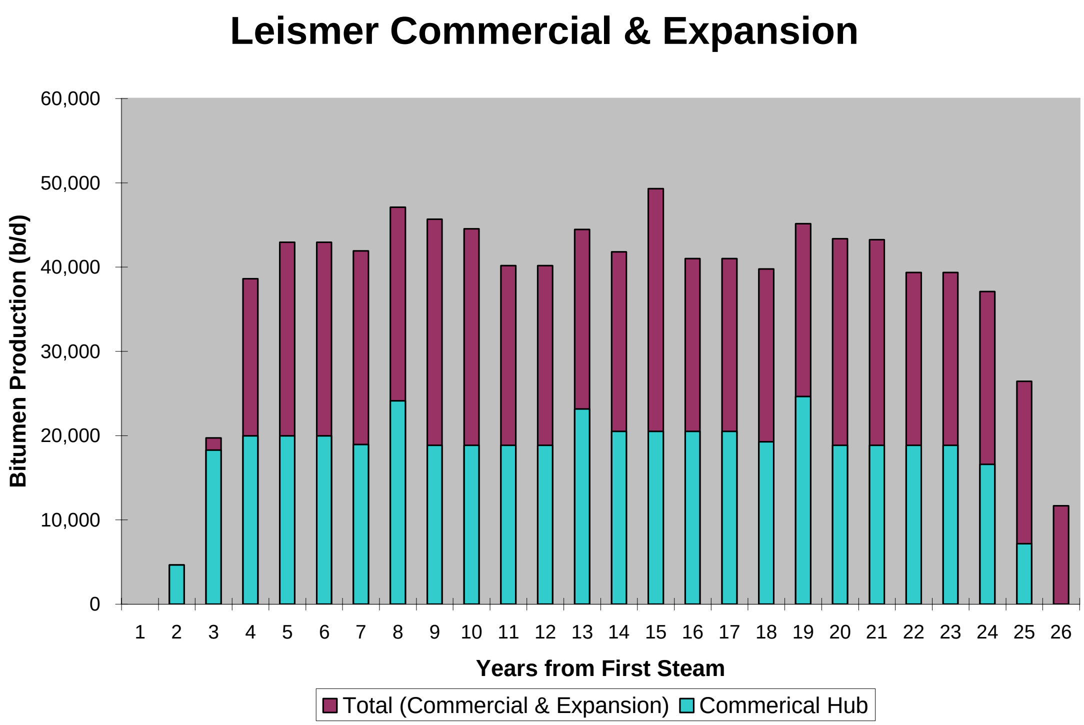
6) StatoilHydro has stated that the overall Kai Kos Dehseh development will target production of 220 000 bpd. The applied for hubs (Leismer up to the Expansion hub, and Corner) each contemplate production of up to 40 000 bpd under the current application.

a. Provide life of project production estimates for each production area, Leismer and Corner, as individual projects.

RESPONSE

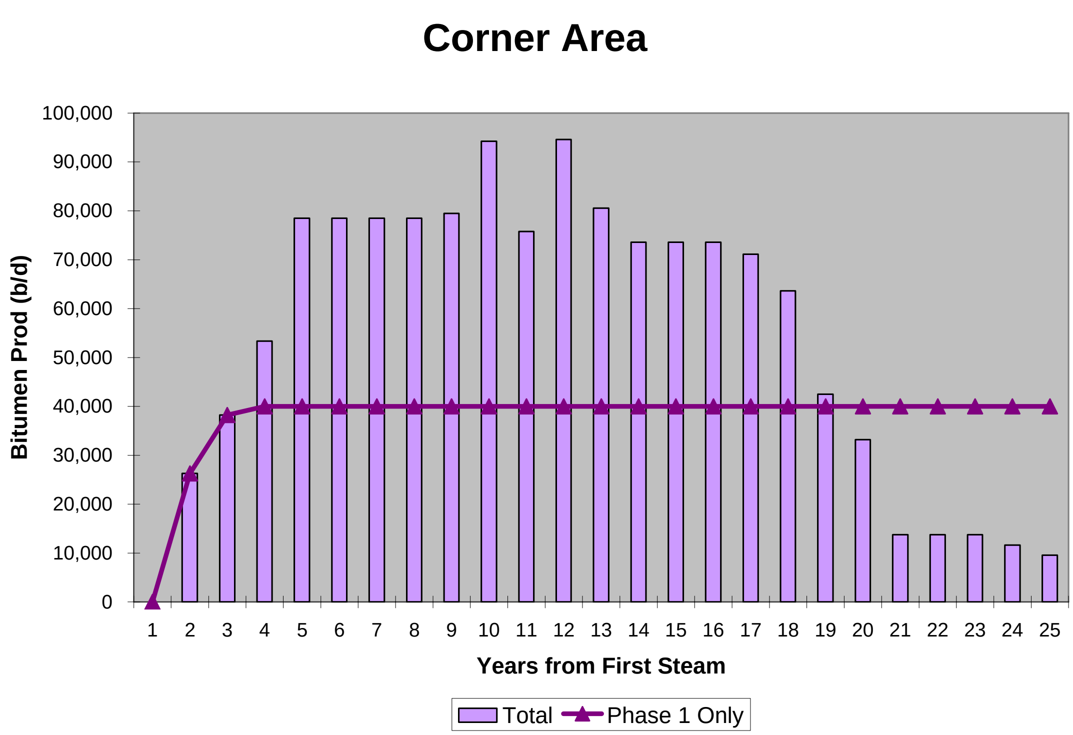
Figure 6-1 below is the production estimate for Leismer production area, which includes the Leismer Commercial Hub (SIR(3) #5) and Leismer Expansion Hub totaling 40,000 bpd.

Figure 6-1



The initial development of 40,000 bpd for Corner is as applied for under Appendix C (EIA, Volume 1). Amendments of the requested Approval will be made in the future to increase the over-all capacity of Corner, as appropriate. If Corner were developed as a Phase 1 only facility, then the production would last beyond 25 years. Figure 6-2 indicates the total potential at Corner of 80 000 bpd in two phases as indicated below.

Figure 6-2



D. PUBLIC CONSULTATION
7) Provide an update, including dates of any communications or meetings, on the status of consultation with all project stakeholders, including but not limited to:

a. Chipewyan Prairie Dene First Nation IRC,

b. Metis Nation Local 1935,

c. Paramount Energy Trust, and

d. Oil Sands Environmental Coalition.

<u>RESPONSE</u>

StatoilHydro continues to engage local communities that are located in close proximity to its KKD Project and is presently involved in several initiatives, which provide opportunities to discuss and address questions and concerns. These initiatives include Traditional Knowledge Studies, Open Houses, and consultation meetings. Additional details relating to these and other consultation activities are below outlined in Table 7-1.

On August 11, 2009 StatoilHydro participated in a joint Open House with AENV, which follows the consultation process outlined by the Conklin Community. StatoilHydro participated in the Conklin Fall Trade Show on September 9, 2009, and the luncheon with the Lac La Biche Chamber of Chamber of Commerce, and Portage College, where the local MLA had also been invited. Presentations will also be held this Fall to outline the 2009/2010 OSE drilling and water programs to the Lac La Biche Community, Fort McMurray First Nation and the CPDFN.

a. Chipewyan Prairie Dene First Nation (CPDFN) IRC
On August 20, 2007, CPDFN filed a Letter of Objection relating to the KKD Project Application.

Since the last update on public consultation submitted on July 23, 2008 in the response to SIR(1) #2(a), StatoilHydro has continued to engage CPDFN in the discussion of issues relating to the KKD Project and other StatoilHydro activities in the area. In response to CPDFN's concerns regarding the proposed KKD EIA, StatoilHydro sponsored, at CPDFN's direction, an independent third-party review of the KKD EIA. Following this Review, a two-day workshop was organized in November, 2008 to enable CPDFN and StatoilHydro to examine and discuss the issues identified. StatoilHydro then prepared a plain language document, which summarized the discussions from the Review and the two-day Workshop. CPDFN is currently reviewing the Plain Language Document with a commitment to respond by August 17, 2009.

Since 2007, StatoilHydro has participated with CPDFN in an ongoing Traditional Ecological Knowledge (TEK) Study. The two parties decided to move into the final stage of the Study in late 2008. A final round of interviews was held with 13 Elders in January, 2009. Based on the content of these interviews, it was determined that further information-gathering was required involving two Elders in a particular area on the Corner Project lease. StatoilHydro has prepared a draft TEK Report, which was delivered to CPDFN during the week of August 4, 2009. CPDFN has committed to respond to the contents of this Report by August 17, 2009.

The CPDFN has requested a more in-depth review of the issues relating to water sourcing and disposal, and the parties have agreed to meet to discuss these issues during September, 2009.

On September 9, 2009, StatoilHydro met with representatives of CPDFN to discuss the framework for a mutual benefits agreement. Both parties agreed to meet in the near future to continue the process.

b. Metis Nation of Alberta, Local 1935 (MNA 1935)
On July 9, 2008, MNA 1935 filed a Statement of Concern (SOC) relating to the KKD Project Application. Following a discussion on January 20, 2009, MNA 1935 was informed by Alberta Environment (AENV) that their SOC had not been accepted. On May 5, 2009, StatoilHydro sent a letter to the MNA 1935 explaining StatoilHydro's priorities for consultation, and opportunities to participate in the consultation process for the Métis people living in the identified local Communities. In its May 5th letter, StatoilHydro extended an invitation to MNA 1935 to meet and share information relating to the plans for the KKD Project.

Quintal Family
On July, 16 2009, letters relating to the KKD Project were faxed to the ERCB and AENV by Osborne Quintal, Verna Quintal-Janvier, Valerie Quintal, Veronica Quintal-Atlook and Margaret Quintal. The five letters dealt with the same, or very similar issues, relating to potential effects of the KKD Project, including those affecting: traditional land use in general, as well as particularly relating to the use of a family trap line; water levels and quality; cumulative/additive effects in relation to other projects in the area; biodiversity; spiritual sites and sacred areas; and land markings.

In response to subsequent discussions with StatoilHydro, the Quintal family filed a revised Statement of Concern on August 20th, 2009. In the revised SOC, the Quintals had narrowed their focus to two main issues: 1/ avoidance and/or mitigation of impacts on the trapping area; and 2/ participation in business opportunities associated with the KKD Project. In respect of more general issues raised previously, the Quintal family has confirmed that it is appropriate to use the Conklin Resource Development Advisory Committee process that has been already initiated within the Community to address such issues as water levels and quality, cumulative effects relating to the KKD Project, and socio-economic impacts on the community.

By way of background, StatoilHydro has been in contact with the Quintal family beginning in the 2005/06 drilling season to the present. StatoilHydro has committed to a Traditional Knowledge recording initiative with the family. Further, FMA Heritage Resources Consultants Inc. on behalf of StatoilHydro presented the Quintal family an Information Sharing Agreement with FMA Heritage Resources Consultants Inc. and StatoilHydro in January, 2008. Despite conversations between the StatoilHydro and the Quintal family in regards to the Information Sharing Agreement, the Agreement has yet to be signed by the Quintals.

From 2007 to present, StatoilHydro has participated with the Conklin Métis Community to conduct a Traditional Land Use Study, in which various members of the Quintal Family were also involved. In addition, from 2007 to present, StatoilHydro has engaged the Conklin Métis Local and the Conklin Community in the Conklin Resource Development Advisory Committee (CRDAC) consultation process. Margaret Quintal is a Member of the CRDAC Board and been fully involved in the process. Verna Quintal-Janvier is currently an employee of the CRDAC organization and has also participated in the KKD Project consultation activities. The CRDAC consultation process includes issues identification activities involving the entire Community.

On February 14, 2007, Osborne Quintal entered into an Agreement and General Release relating to Trap Line 1535 with North American Oil Sands Corporation (NAOSC - now StatoilHydro by way of amalgamation). Mr. Quintal also committed to confirm with governmental agencies his non-objection to NAOSC's activities for the duration of the Agreement, which extends to December 31, 2025.

Most recently, StatoilHydro representatives met with the Quintal family and their lawyer on August 25 and September 9, 2009. Telephone calls and letters have also been exchanged between the parties during this period as part of the ongoing consultation activities between the family and StatoilHydro. Action items arising from those meetings include the exchange of maps to facilitate the discussion on traditional land use and continued dialogue on possible business/contract service opportunities associated with the KKD Project.

c. Paramount Energy Trust (Paramount)
StatoilHydro provided Paramount with a copy of the Application on April 30, 2008. On May 22, 2008, Paramount sent a letter to the ERCB, with a copy to StatoilHydro, expressing concerns relating to the KKD Project Application and requesting an extention of the ERCB response deadline from July 9, 2008 to August 31, 2008. On August 29, 2008, Paramount sent a letter to StatoilHydro expressing its concerns related to the SAGD process proposed in the KKD Project Application and its potential effect on Paramount's shut-in natural gas resources. On May 1, 2009, StatoilHydro sent Paramount a letter responding to each of its concerns and offering to discuss any remaining issue that Paramount may have.

Since its May1st letter, StatoilHydro's Commercial and Land Manager has met with Paramount's Vice President Land, Legal & Acquisitions and its Manager, Acquisitions & Divestments on June 10, 2009, and met with Vice President Land, Legal & Acquisitions once again on June 25, 2009 to further discuss the Application and Paramount's concerns. These meetings resulted in arranging a technical meeting at StatoilHydro's offices on July 23, 2009 to further discuss the nature of Paramount's concerns relating to the potential impact of the KKD Project on its natural gas resources.

The July 23rd technical meeting was attended by a number geology and reservoir engineering managers from both StatoilHydro and Paramount to discus options for resolving Paramount's concerns. It was contemplated that a Technical Study Boundary (TSB) could be established by mutual agreement around the Leismer Demonstration Project (LDP) area where the initial steam would be first introduced. Technical details pertaining to the TSB would then be reviewed, including: gas zones and pressures; volumes of associated gas, if any; and specific well logs. The idea would be to start with a relatively small area around the LDP to develop a model for exchange of information and issue resolution in other areas of the KKD Project Area, such as Corner. The date of the next technical meeting was not specifically determined.

d. Oil Sands Environmental Coalition (OSEC).
On July 8, 2008, StatoilHydro received a letter from OSEC expressing concerns relating to the KKD Project Application, and oil sands development in general. On November 5, 2008, StatoilHydro received a copy of a letter from AENV accepting OSEC's July 8th letter as a SOC under both the *Water Act* and the *Environmental Protection and Enhancement Act* ("EPEA").

On May 6, 2009, StatoiHydro sent a letter responding to all of the questions and concerns raised in OSEC's July 8th letter, with a copy sent to the ERCB and AENV. StatoilHydro's letter specifically addressed OSEC's issues relating to environmental baseline information, greenhouse gas emissions, biodiversity monitoring, site reclamation, as well as others. In its letter, StatoilHydro also offered to meet with OSEC to further discuss its response. To date, OSEC has not accepted StatoilHydro's invitation to meet.

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
Athabasca Chipewyan First Nation				
28-Nov-08	Athabasca Chipewyan First Nation (ACFN) IRC Environment Coordinator	Meeting	StatoilHydro (SHC) representative delivered a package outlining the SHC KKD Project and winter plans to the ACFN IRC office.	
1-Dec-08	IRC Environment Coordinator	Fax	ACFN Environment Coordinator requested that relevant GIS information for the proposed development areas, including exploration activities, be sent to enable ACFN to understand possible impacts of development on ACFN Aboriginal and treaty rights.	
18-Dec-08	IRC Environment Coordinator	Email	SHC responding to the fax recieved requesting GIS data, stating that SHC would respond formally in Jan 2009.	
29-Jan-09	IRC Environment Coordinator	Email	SHC is currently working on a Confidentiality Agreement (CA) and it is expected to be forwarded to ACFN. After both parties have agreed to the CA, SHC will forward the GIS information and then would like to arrange a follow-up meeting to discuss the findings and potential next steps in the consultation process.	
11-Feb-09	IRC Environment Coordinator	Email	Environment Coordinator responded to SHC Jan 29th email and asked her to send the GIS data.	
11-Feb-09	IRC Environment Coordinator	Email	SHC sent the GIS data of the KKD Project lease areas.	
20-Feb-09	IRC Environment Coordinator	Email	SHC sent IRC the GIS data for the SHC KKD Project footprint.	
3-Jun-09	IRC Environment Coordinator	Phone discussion	SHC let Environment Coordinator know that SHC would be available on Jun 10 to meet with ACFN if they would like to meet. Environment Coordinator indicated that they are not interested in meeting with SHC on the KKD project.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
Anzac Community				
24-Jun-09	Community Members	Anzac Community Centre Open House	Majority of Community members' discussions focused on procurement and employment opportunities within the KKD Project. Discussions with some Community members regarding cumulative effects.	
Beaver Lake Cree Nation				
27-Sep-07	Beaver Lake Cree Nation (BLCN) Business and Intergovernmental Representatives	BLCN Intergovernmental Affairs & Industry Relations Office, Lac La Biche	Initial introduction of North American to BLCN. BLCN asked for KKD Project and SHC corporate information.	North American commits to make EIA information available to BLCN.
17-Jan-08	BLCN Intergovernmental Representatives & BLCN Chief and one Councillor	BLCN Intergovernmental Affairs & Industry Relations Office, Lac La Biche	Meeting to discuss a working relationship. SHC explained the KKD Project, and upcoming developments. SHC committed to a next steps working process including an upcoming Elders and Chief & Council meeting. To implement this consultation process, SHC committed to a proposed fee to be fully agreed to once SHC received in writing an itemized break-down of the budget.	BLFN did not provide a budget itemizing information to SHC, in order for SHC to make payment for engagement/consultation agreement.
3-Oct-08	BLCN Business & Intergovernmental Representative	Email	SHC representative emails BLCN Business & Intergovernmental Representative to make introduction as a new employee working on Community Consultation and Regulatory, and has been given the file on the SHC pipeline projects and consultation efforts with BLCN. She explained that SHC feels that we have attempted to meet with BLCN and understand concerns regarding BLCN treaty rights and traditional uses; and that SHC is willing to continue consultation on the pipeline project and other SHC projects.	
6-Nov-08	BLCN Business & Intergovernmental Representative; legal counsel and Representatives	Meeting	SHC representatives and outside counsel met with BLCN representative BLCN Business & Intergovernmental Representative and BLCN external counsel and consultants.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
26-Nov-08	Legal counsel for BLCN; legal assistant	Email	BLCN Office representative forwarded a letter and attached document via email from BLCN legal counsel. The letter stated that further to recent discussion, BLCN have prepared a document titled "Consultation and Monitoring Project" and are forwarding it to SHC for review and discussion.	
15-Dec-08	Legal counsel for BLCN; legal assistant; IRC Director	Email	BLCN forwarded a letter via email from BLCN legal counsel advising that they had not received a response in regards to the letter concerning the Consultation and Monitoring Project, dated November 26, 2008 and that they look forward to receiving a response to this matter as soon as available.	
22-Dec-08	BLCN legal counsel	Email	SHC legal counsel replied to BLCN legal counsel to express thanks for the follow-up letter attached to the December 15 email from BLCN office. SHC explained that it was not apparent from the initial letter of Nov 26, 2008 that a response was expected and thanked him for that clarification.	
17-Feb-09	BLCN Business & Intergovernmental Director	Email	Business & Intergovernmental Director forwarded industry representatives a letter titled, "Proponent Application Processing Changes Effective Immediately". The letter outlined that all proponents applying for projects within the BLCN Traditional Territory are required to provide an administration and technology fee per application effective immediately. The new fee is designed to decrease turn around time of the initial processing of applications, etc.	
10-Jun-09	BLCN legal counsel	Letter	SHC addressed BLCN document entitled "Consultation and Monitoring Project". SHC is seeking greater clarification from BLCN on the purpose of the document and for them to provide clarity on the nature of items addressed in the document that SHC is able to address.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
Chard Community				
18-Feb-09	Chard Metis Local Representative	Meeting	SHC met with Chard Metis Local representative to discuss the consultation process. SHC offered FMA Heritage Resources Inc.(FMA) to interview Chard Elders as part of the EIA and to provide historical documentation for the Community. The Chard Metis Local representative was not supportive of the idea, rather he suggested a meeting be set up with the Community and that he would forward a consultation budget to SHC.	Chard Metis Local to send consultation budget.
26-Feb-09	Metis Local President	Phone discussion	Chard Metis Local President contacted SHC and she agreed that the Elders interviews were a good idea and asked that she be involved in helping organize. SHC said that FMA would contact her to discuss details.	FMA to contact the President to discuss Elders interviews
2-Apr-09	Industry partners	Chard	Industry Partners meet with the Chard Metis Local to discuss the proposed engagement process with the Community.	Various outcomes with parties agreeing to continuing to developing the engagement process with Chard
7-Apr-09	Chard Metis Local	Phone discussion	Industry partners had a phone meeting to review April 2 meeting with Chard and discuss next steps.	
22-Apr-09	Chard Metis Local	Chard	Discussion on how Industry is going to engage with the Chard Metis Local regarding budget and expectations of all parties.	
26-May-09	Other industry groups	Chard	Continued discussions between companies and the Chard Metis Local on a process of industry engagement with them, and what they will and will not fund. Collective agreement to move various processes forward.	
6-Jun-09	Chard Metis Local Representative	Phone discussion	Ongoing discussion regarding consultation process.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
22-Jun-09	Chard Metis Local Representative	Chard	SHC received an update on the development of the Community consultation process for the Chard Metis Local. They asked for the "Plain Language, Project EIA" document that SHC has prepared with the CPDFN IRC. SHC advised them to contact the CPDFN IRC to ask for a copy. SHC open house in Janvier South was held immediately after this meeting.	SHC met with representative, set Jun 11 to meet and have the Open House in Janvier South.
25-Jun-09	Other Industry Partners	Phone discussion	The companies collectively engaging the Chard Metis Local met as a group to discuss the progress and next steps relating to various developments.	
Conklin Community				
19-Jan-08	Conklin Metis Local (CML) and Conklin Community Association	Chateau Louis, Edmonton	Industry meeting with CML about how the CML and CCA have formed a joint committee to engage with different companies.	
28-May-08	Conklin Community members, Conklin Metis Local and Conklin Community Association	Conklin Community Centre	Issues identification meetings with Elders, youth and adults throughout the day. Excellent discussion and information sharing between the four industry parties and Community members.	
1-Jun-08	Conklin Resource Development Advisory Committee (CRDAC) Advisor	Phone/email discussions	New advisory committee established as the Conklin Resource Development Advisory Committee (CRDAC). Local industry collectively working with the CRDAC to create an effective partnership model meeting the consultation and Community needs based on performance. SHC has provided significant mentoring and support as the CRDAC Community members develop their process. SHC has committed to funding this important Community process.	Ongoing next steps. The CRDAC will host an Industry Trade Show in Conklin on Sept 24, which SHC will be attending.
21-Jun-08	Letter to Alberta Environment and ERCB from Conklin Metis Local #193	Letter	Approval of consultation plan with SHC.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
7-Jul-08	Conklin Community Association Board of Directors	Conklin Community Centre	Update on Leismer Airdrome Limited (LAL), owned by SHC. CCA would like information on noise study. LAL has specifically had landing approach to be several km north of Conklin to address Conklin's concerns of aircraft noise. Of SHC's 100+ flights over the past winter, meeting attendees stated they had not heard any of them.	
16-Jul-08	Conklin Traditional Land Use Study Coordinator; HLFN	SHC Office, Lac La Biche training meeting	SHC and FMA provided several days of GIS training to local young people. TLU Coordinator specifically needed this training to complete next steps with the Conklin Métis TLUS. SHC also provided computer and software equipment to be property of the Conklin Métis TLUS project for the training and on going use.	
19-Oct-08	CRDAC	Winifred Lake, Alberta - Retreat.	2-day meeting/retreat for CRDAC including Community representatives and industry representatives. Agenda included: relationship-building exercise, common understanding on a) consultation, b) Aboriginal Law, c) regulatory process in Alberta - board effectiveness and good governance - discussion/development of a work plan and action plan for the CRDAC. Action Plan - agreed on revised schedule	
12-Nov-08	CRDAC 8-10 Conklin Elders (8-10) exact number TBD when report received. 5 Conklin Youth Conklin Adults	Conklin, Alberta, Workshop	3 workshops with Conklin Elders, Youth and Adults to provide feedback on the issues heard May 28 2008 and to work on solutions to issues.	waiting for May 28 and Nov 12 Issues ID reports

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
4-Dec-08	CRDAC Advisor	Edmonton, Alberta	Meeting with CML#193/CRDAC Community advisor to determine next steps on Joint Action Plan for regulatory milestones: revised action plan, updated on SHC regulatory status and Community review, community bulletin, continued Issues ID process, TLU maps/issues/concerns, MOU, etc. Agreed that Community representative is to provide maps reflecting Conklin TLUS data overlaid onto SHC lease areas to determine possible impact areas for last round of Supplemental Information Requests (SIR's). EIA technical review meetings to be held possibly February. The goal of drafting a Memorandum of Understanding was discussed for 2nd quarter of 2009.	CRDAC Advisor to provide: Issues ID report by end of year; TKS/TLU map with overlay of SHC lease areas to determine possible impacts; update letter to GOA that CRDAC is acceptable consultation to Conklin Community; MOU/MOA document for SHC review;
9-Dec-08	CRDAC	Meeting	Monthly CRDAC meeting, focuses on industry development in the area.	Committee formed for GOA interface Committee formed to build community plan
14-Jan-09	CRDAC	Meeting	Monthly CRDAC meeting, focuses on industry development in the area.	CRDAC/Industry representatives to set-up meeting with AENV SHC Technical Review Meetings plan for Spring
15-Jan-09	CRDAC Advisor	Email	CRDAC advisor emailed AENV Regional Director, Northern Region to explain in writing the CRDAC process. Furthermore, the CRDAC, as the representative leadership for Conklin, requests that the regulators acknowledge these interfaces as effective engagement in project specific correspondence.	
15-Jan-09	CRDAC Advisor	Email	CRDAC Advisor sent a series of Maps identifying TLU Sites within SHC KKD Project Area and briefing note (data collected from Conklin Métis Local 193 Community TLUS).	

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
18-Jan-09	CRDAC Advisor	Email discussion	CRDAC Advisor sent Community Enhancement Society Guidelines and donation request letter. She requested that this be shared with corporate executives to make a decision on donation dollars and that the enhancement society contributions will be identified in Community agreements as part of the mitigation of project impacts.	
26-Feb-09	CRDAC indsutry partners	Meeting	Monthly CRDAC meeting, focuses on industry development in the area.	
19-Mar-09	CRDAC	Meeting	Monthly CRDAC meeting, focuses on industry development in the area.	RMWB engagement: SHC talk to the RM prior to the meeting with the RM and Housing Authority. Relay industries support of the process. SHC to attend the meeting with the RM and Housing Mar 20th.
21-Apr-09	CRDAC	Conklin, meeting	Specific meeting to review and follow-up on the Issues Identification Meeting with Conklin Community people in May 2008. Group received and reviewed the Issues Management Report.	
22-Apr-09	CRDAC	Conklin, meeting	Review and discussion around CRDAC process and business. SHC to prepare project information newsletter for community for August community meeting. Water was a main topic of discussion - SHC water expert explained in detail about the water systems in the areas, the water being access by SHC and how the SHC project was processing the water.	
13-May-09	CRDAC	Conklin, meeting	Monthly Industry partner meeting with CRDAC. SHC is to present Project to the CRDAC, Community and Industry Partners in August 09.	

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
14-May-09	Conklin Community and CRDAC	Conklin, Spring Open House	SHC participated in the Open House with Conklin, presenting updates on our Leismer project and upcoming Project developments. It was an opportunity to connect with local business people on economic opportunities and employment.	
3-Jun-09	CRDAC Advisor	Phone discussion	CRDAC questions about SHC use of water, and other questions regarding SHC activities	SHC provided clarification relating to water issues and committed to bring water experts to the next coffee house.
10-Jun-09	CRDAC Board	Leismer site facility tour	SHC KKD site tour on June 16th with CRDAC. Various questions and discussion points.	
11-Jun-09	CRDAC Advisor and Alberta Environment Representatives	Edmonton	Discussion on a tentative process and schedule for communication between SHC, the Conklin Community and AENV on the KKD In-Situ Project. Discussions about priorities for all parties. Reviewed upcoming Aug 11 Open House in Conklin.	SHC to prepare bulletin for the Aug 11 meeting in the Community
17-Jun-09	CRDAC and Community - Coffee House	Conklin, Community Meeting	Monthly CRDAC meeting, focuses on industry development in the area.	
18-Jun-09	CRDAC	Conklin, meeting	Monthly CRDAC meeting, focuses on industry development in the area.	
Chipewyan Prairie Dene First Nation				
08-Jan-08	Chief and Councillors, Elders, CPDFN IRC Director	Sawridge Hotel, Ft. McMurray	SHC President & CEO, Executive and other representative met with Chief and Council to discuss next steps in moving forward in relationship/partnership building. Agreement by both parties to draft, agree on and sign a working agreement.	CPDFN to deliver first draft agreement to SHC.
23-Jan-08	CPDFN Chief & Council, Elders, CPDFN IRC Director		SHC President & CEO, Executive and other representative met with Chief & Council to discuss next steps in moving forward in relationship/partnership building. Agreement by both parties to draft, agree on and sign a working agreement. CPDFN to deliver first draft agreement to SHC.	CPDFN to deliver first draft agreement to SHC.

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
25-Feb-08	CPDFN IRC Director, CPDFN IRC Environment Coordinator, CPDFN Regulatory Coordinator and Councillors	Sawridge Hotel, Ft. McMurray	Discussion about next steps in developing and signing IRC Agreement with SHC.	CPDFN IRC Director committed to getting a next draft agreement to SHC.
1-Apr-08	IRC Director and Environment Coordinator	Phone discussion	Phone meetings and discussion to move progress forward on getting IRC agreements developed and signed.	SHC waiting for information from CPDFN to start the agreement development process.
1-Jun-08	CPDFN Technical Review filed with Alberta Environment in Spring 08.	Written response	SHC has spent the last several months formulating a response to CPDFN Technical Review filed with the Alberta Government on the KKD Application.	SHC to finalize response in Fall 08 and request opportunity to review in person with CPDFN at this time.
1-Jun-08	IRC Director and Environment Coordinator	Phone/email discussions	Discussions in drafting a Consultation Protocol Agreement with the CPDFN IRC.	
1-Jul-08	IRC Director, Environment Coordinator and TLU Coordinator	Phone/email discussions	Discussion about next steps in completing the Traditional Knowledge Studies relating to the KKD Application. Meeting on Aug 26 with TLU Coordinator to identify next working steps with Elders. Last Traditional Knowledge Study work with the CPDFN Elders was Summer 2007. At this last meeting it was identified that Elders wanted to do further field studies with SHC.	
6-Oct-08	Chief & Council	StatoilHydro Calgary	Meeting to share information on SHC 2008/2009 planned activities including: seismic, drilling, pipelines, facilities, aerodrome, Caribou Protection Plan and business opportunities. CPDFN Chief & Council shared information on CPDFN protocol and business interests.	commitment to continue to work together on a go-forward basis
8-Oct-08	IRC Director, Environment Coordinator and Regulatory Coordinator	SHC Calgary	Various discussion points, including CPDFN issues with SHC relationship, overview of regulatory activities for KKD Application, and planned review of technical issues associated with EIA.	

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
5-Nov-08	IRC Environment Coordinator	SHC Calgary	Technical review conducted with CPDFN, as part of the SHC commitment to KKD consultation process. This review included consultants MSES and Matrix Solutions, and comprised a 2-day workshop studying various technical aspects of the proposed KKD Project.	
20-Nov-08	IRC Environment Coordinator and TLU Coordinator	CPDFN Band Office;	Meeting to discuss next steps of TK Study with CPDFN. Preliminary plan includes: Phase 1 in December 2008 - 12 Elder interviews to determine issues/concerns and documenting sites/locales within SHC lease areas; report based on interviews; Phase 2 in Spring 2009 - field studies to ground truth previously identified sites/locales. Plan is currently under review by IRC Director.	
3-Dec-08	IRC Environment Coordinator	Phone discussion	SHC spoke with Environment Coordinator regarding the status of the TK Study. CPDFN IRC indicated that it may be too short notice now to get things ready for the meeting and interviews before Christmas, they indicated that both parties still needed to talk about the Study plans and that he would get back to SHC on this.	
08-Jan-09	IRC Environment Coordinator	Email	Environment coordinator emailed SHC representative to discuss next steps for the TK Study and he suggested that the TK Study phase 1 (interviews) start Jan 26, 2009.	
09-Jan-09	IRC Environment Coordinator	Email	SHC representative replied to Environment Coordinator with regards to the upcoming TK Study start up for Jan 26, 2009. It is agreed that the TK Study parameters were to be as follows: • Phase 1 of the Study will include interviews with 10-15 Elders and Knowledge Holders as selected by CPDFN. The interviewees will be familiar with the Project, lease areas and primary areas of interest within lease areas.	

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
26-Jan-09	IRC Environment Coordinator and TLU Coordinator; 13 respondents interviewed	Meeting	13 Elder and Knowledge Holder/active land users interviews conducted by TLU Coordinator and FMA the week of Jan 26-30.	
27-Jan-09	IRC Environment Coordinator	Meeting	Meeting with SHC representatives and CPDFN interview participants. SHC representatives arrived at meeting but Elders/Knowledge Holders were not present. SHC representatives spoke with Band councillors and Community members, attended lunch, however, planned meeting did not occur.	
29-Jan-09	IRC Environment Coordinator; TLU Coordinator; and 2 Elders	Field Visit	SHC Corner lease areas. Field visits for TK Study to GPS and take photographs of specific areas of interest (cabins and TLU areas) within the Corner lease area. These areas are only accessible in winter.	
5-Feb-09	IRC Environment Coordinator	Email	As part of the REMA (Regional Environmental Management Association Group) that Environment Coordinator leads, a funding request was submitted for a Traditional Food Study being conducted by Jacques Whitford AXYS on behalf of CPDFN and REMA.	
9-Feb-09	IRC Environment Coordinator	Email	SHC emailed IRC Environment Coordinator to ask him to provide her with the names of the Elders and dates that they went into the field.	
9-Feb-09	IRC Environment Coordinator	phone call	IRC Environment Coordinator called SHC to inform that he took two Elders out to the Corner Lease area for 2 days of field work. They took photos and GPS locations of cabins and other areas of interest that were only accessible in winter. SHC asked for more details about the Traditional Food Study proposal and it was suggested SHC contact the person at EnCana who was spearheading the study for further information.	IRC to provide FMA Heritage with all data collected awaiting data; still working on terms-of-reference

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
10-Feb-09	IRC Environment Coordinator	Email	IRC Environment Coordinator responded to SHC email providing the names of participants in the field visit and dates.	Contact EnCana for more information; wait to hear back end of February.
27-Mar-09	IRC Environment Coordinator	Email	SHC requested a meeting to discuss next steps.	Waiting to hear back from Environment Coordinator
5-May-09	CPDFN Chief	Letter	Letter is regarding the CPDFN Letter of Objection relating to North American's Oil Sands Corporation KKD Project. Specifically, SHC addresses how the company has addressed the two issued raised the CPDFN Letter of Objection: 1. status of consultation; and 2. independent third-party review.	
27-May-09	IRC Director	Letter	The letter from CPDFN addresses the SHC letter of May 5th to the Chief, stating that CPDFN is consulting with SHC and discussing the status of the process.	
8-Jun-09	CPDFN Chief, CPDFN Director, CPDFN Economic and Business Development, CPDFN Band Member	Leismer, west of Conklin; Leismer Facility Site Tour	A number of issues discussed, including recognition of CPDFN in the ISR plan, Leismer Demonstration Project (LDP) progress, business opportunities, and the regulatory status of the KKD Project. A copy of the Plain Language Summary was provided to the IRC Director, and a commitment was made to work on a Mutual Cooperation Protocol.	
2-Jul-09		Letter	Letter is in follow-up to meeting after the Jun 8th Leismer site tour. It acknowledges the upcoming July 7th regulatory consultation meeting with CPDFN IRC. It also provides a discussion on the Mutual Cooperation Protocol Process.	

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DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
6-Jul-09	CPDFN Chief	Letter	Letter was printed, signed and hand-delivered to SHC during the July 7th, 2009 meeting between SHC and CPDFN in Fort McMurray. Letter notes that CPDFN feels they are not being given the proper priority by SHC. CPDFN identifies their lead negotiator for the Mutual Cooperation Protocol with SHC. CPDFN states that they requested funds in good faith and request that particular local contractors be given priority consideration for contract work. SHC is going to reprint the ISR Plan with CPDFN's full name noted in the document. Accordingly, the re-print will be sent to CPDFN with an explanation on how to change the Community's name from Janvier to CPDFN with the Alberta Government on official maps.	
7-Jul-09	CPDFN Chief & Councillor, IRC Director, Environment Coordinator, Regulatory Coordinator & CPDFN Business Representative	meeting	Meeting to facilitate ongoing consultation between SHC and CPDFN, relating to various discussion items. The Plain Language Summary, and TK studies were discussed that are specific to the KKD Application. CPDFN to review Plain Language Summary and report by August 17th. Also in September, TK field work to take place, and CPDFN wished to have another review of water issues, similar to the previous technical review, in September.	

Table 7-1 Kai Kos Dehseh Consultation Update

Date	Community Participants	Meeting/Event	Outcomes	Follow-up
22-Jul-09	Chief Vern Janvier	letter	SHC reply to Chief Janvier letter to SHC, dated July 7, 2009. Addressing several items; 1) re-affrimg SHC's commitment to the Mutual Cooperation Protocol process, with a request that the CPDFN negotiator contact SHC to move ahead accordingly; 2) SHC would review published documents, Report to Community 2008 and Intergrity and Social Responsibility Plan to consider how CPDFN is represented as per their concerns; 3) a status of local CPDFN contractors currently working on the project construction was reviewed; 4) it is noted that SHC and the former North American Oil Sands have been working toward a protocol agreement since 2005 with CPDFN and look forward to finalizing one now. It is also noted that the Food Study is progress with SHC's support, the Plain Language review back to SHC from CPDFN by Aug 17 and TEK Study to be delivered to CPDFN by Aug 4 and reviewed by CPDFN by Aug 17.	
Fort McMurray First Nation				
18-Mar-08	FMFN Elder's Coordinator and Elder Community	Anzac Community Hall	Meeting with Elders in completing Traditional Knowledge Study work for the KKD Project. Elders shared concerns relating to cumulative impacts.	SHC committed to providing a presentation on employment and training opportunities for the local high school. A field tour to a special location in Hangingstone lease to be arranged with several Elders. SHC will also arrange to have the specialist who completed the environment studies to make a presentation to the Elders.

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
15-May-08	Two Elders	FMFN and area helicopter tour	Special helicopter tour to look for and document a sacred area in the Hangingstone area, as the request of Elders during the Traditional Knowledge Study engagement process. SHC representatives and Elders flew for several hours to find and observe sacred area, they were not successful in positively identifying the exact location, although they identified areas of possibilities.	Elders asked for another opportunity to find sacred area in late Fall 08 when there was an appropriate amount of snow on the ground for best conditions. One Elder committed to contacting SHC when he felt the time was right to do another fly-over.
1-Jun-08	IRC Director and Elder's Coordinator.	Phone/email	Discussions and planning to meet with Chief & Council and IRC on June 11. SHC arranged to have the water and vegetation specialist, who conducted the studies, come to the FMFN Community to provide a plain langage presentation to the Elders. This was a request by the Elders at the last Elders meeting in the Spring 08. The proposed date was cancelled by the IRC.	SHC still prepared to bring a specialist to present to the Elders and provide a presentation of the Traditional Knowledge Study Report to the Elders and FMFN IRC for approval.
11-Jun-08	IRC Director; IRC Environment Coordinator & IRC Representative		Meeting with new IRC representatives, information sharing about what has been accomplished to date with the EIA TK Study with FMFN Elders and working with the IRC. The IRC requested a copy of SHC's work file with FMFN. They also expressed the need for SHC to provide work opportunities to local Community members.	SHC has committed to providing two laptop computers to the FMFN IRC to assist with the office function and a complete file of correspondence to IRC representative. SHC continues to work with local FMFN contractors.
5-Nov-08	IRC Director and Fort McMurray First Nation (FMFN) representative		Nov 5, 2008 Meeting, focussed on winter activities, but also discussion on TK studies.	Commitments: 1. SHC and IRC representatives to discuss next steps for TLU 2. discuss third-party EIA review and to how best provide FMFN with information 3. How to best to involve FMFN youth in field studies? 4. FMFN to provide list of Band-owned companies
5-Nov-08	IRC Director, Elder's Coordinator and IRC Representative	Meeting	Discussion relating to a number of items, including TK, and sites of spritual significance.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
19-Nov-08	IRC Director	Email	SHC representative emailed IRC Director to say as per their short discussion on Monday of this week please accept this email as a commitment to the Ft. McMurray First Nation Industrial Relations Corporation (FMFN IRC) that we; SHC would like to enter into a formal bi-lateral IRC agreement with FMFN as a full member.	
3-Dec-08	IRC Director, IRC Environment Coordinator	Phone discussion	SHC left messages at the FMFN IRC office for IRC regarding follow-up on the TK Study and third-party review.	
8-Jan-09	IRC Environment Coordinator	FMFN IRC office	SHC representative met with IRC Director to discuss business contracts and TK Study status. Director indicated that there may be some outstanding issues with respect to a SHC bridge crossing and the TK Study. SHC indicated the IRC could contact other SHC representatives for more information.	
12-Jan-09	IRC Director	Phone discussion	SHC emailed IRC regarding outstanding issues with respect to a bridge crossing over an unnamed tributary of the Christina River and the outstanding TK Study.	
21-Jan-09	IRC Environment Coordinator	Email	SHC provided all requested materials (previous emails and Fish Habitat Study) to IRC regarding the bridge crossing and TK Study (questions regarding Elders List, Maps and Draft TK Study report).	
23-Jan-09	IRC Environment Coordinator	Phone discussion	SHC called IRC Director to confirm that she had received all the requested information regarding the bridge crossing and TK Study. IRC Director indicated she had been out of the office but that she had received several emails and would try to review the information over the weekend.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
9-Feb-09	Acting IRC Director	Fort McMurray	Acting IRC director met with Industry partners. Agenda:- IRC roles and responsibilities/commitments from FMFN from Industry funders - draft audited financial statement update (2004-2008) - options for IRC office - Consultation Protocol/IRC agreement revisions/elders participation in consultation actiivites - building IRC funders membership	IRC to send revised IRC budget and follow-up with SHC: March 11th meeting schedule
8-Apr-09	Acting IRC Director	Email	Email requesting a meeting with the FMFN IRC for consultation between SHC and the FMFN.	
30-Apr-09	Acting IRC Director	Email	email to enquire about a next meeting between SHC and the IRC. No response.	
20-May-09	IRC Elder's Coordinator	Phone discussion	Left a message with Environment Coordinator to ask about next steps in getting a response to the TK report given to the FMFN in 2008 - Elders were to review with the IRC and respond to SHC.	
20-May-09	IRC Director	Phone discussion	Left message with IRC Director, but could not because voicemail was full. FMFN has a commitment to respond the SHC TK Report to Elders, for our EIA. Both FMA and SHC have been contacting the IRC for some time to take next steps in the process.	
26-May-09	IRC Elder's Coordinator	Phone discussion	SHC informed IRC that it has the FMFN IRC invoice, but that SHC requires back-up agreement terms for IRC payments. Also, included discussion about the need for another meeting with the Elders to provide a final reivew of the TEK Report.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
9-Jun-09	Five FMFN Elders	Leismer and Cheecham - Leismer site facility tour and Cheecham Terminal site tour	Purpose of tour was to visit the Leismer Project site and explain the SHC pipeline project at Cheecham terminal to the Elders. The Elders asked about the pipeline they saw above ground at the SHC Leismer Site, it was noted that the pipelines connecting the Leismer facility and Cheecham terminal would be underground. It was asked who would be doing the clearing for othe pipeline right-of-way, SHC was able to confirm a FMFM-affiliated contractor would be doing this work.	
8-Jul-09	IRC Director	Phone discussion	SHC representative and IRC Director discussed a meeting and response from FMFN IRC on the SHC FMFN TK report. Director indicated that she was going to look at the schedule and find a time. SHC gave her FMA phone number.	
Heart Lake First Nation				
01-Feb-08	HLFNCO Director	Phone discussion	Telephone calls between SHC and HLFNCO Director regarding SHC funding commitment for multiplex.	funding request letter from HLFNCO.
5-Mar-08	Heart Lake First Nation (HLFN) Chief, HLFNCO Director, HLFNCO Environment Director and HLFN Business Manager	Meeting	HLFN discussed the development of their IRC Office and how they would like to work with SHC. SHC committed to the overall process, and was invited to an Elder's meeting in mid March	
19-Mar-08	HLFNCO Director, Regulatory Director and HLFN Elders	HLFN	Meeting with Elders provided an opportunity for SHC to share updates on development, including proposed pipeline plans. The Elders wish to have a greater understanding of SHC water program. SHC offered to bring in water specialist to discuss the issue in greater detail. SHC also offered the Elders an opportunity to visit development areas. SHC finished meeting with a continued committment to work with the Community.	
1-Apr-08	HLFNCO Director	Phone discussions	Phone discussion: A meeting was planned for late May, HLFN IRC became unavailable.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
11-Jul-08	HLFNCO Director; HLFNCO Regulatory Director	SHC Office Calgary	Discussion to finalize working agreement with HLFN in near future. SHC commited to provide funding for the HLFN Traditional Land Use Study and study outcomes to contribute to SHC's Traditional Knowledge work with the Elders.	
29-Oct-08	HLFNCO Director	Email	HLFN discussed the development of their IRC Office and indicated how they would like to work with SHC. SHC committed to the overall process, and was invited to an Elder's meeting in mid March	
10-Dec-08	HLFNCO Director and HLFNCO Regulatory Director	Devon Canada Offices, Calgary Alberta	The Purpose of this meeting was for HLFN to address Community priorities and commitments to these efforts annually. HLFNCO Director hosted this meeting and presented the business plans for the upcoming year for Community investment, environment, and economic development / employment training. The Regulatory Director provided an update on overall progress of the Consultation Office initiatives and the ongoing Traditional Land Use Study (TLUS). A review of last year's audited financial statements and first two quarters of this year was also provided.	
15-Jan-09	HLFNCO Director and HLFNCO Regulatory Director	Meeting	Update by HLFN on social/environment/economic development priorities with industry partners - specifically relating to the multi-purpose building. SHC committed to providing funding for the building.	Contact HLFNCO Director to ask for official funding request for multi-purpose building.
09-Jun-09	HLFNCO Regulatory Director	Meeting	SHC provided a KKD Project update. SHC made a commitment to help fund a summer program for Community members. Discussed the possibility of doing a mini Open House in HLFN on Jun 23.	It was not possible to have Open House due to a sudden death in the Community.
10-Jul-09	HLFNCO Director	HLFN Community Centre Ground Breaking Ceremony and Pow Wow.	SHC participated in the Community Centre ground breaking ceremony for the multi-purpose building.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
Janvier South				
22-Jun-09	Community Members	Meeting	The Open House team discussed issues relating to the adequacy of Community consultation as raised by local community members. Some attendees expressed concerns relating to impacts on fish and water. The members provided anecdotal evidence that they can no longer drink from local rivers and streams. Other attendees wanted SHC's EIA to be subject to an independent third-party review.	SHC is engaged in significant consultation processes with both the Chard Metis Local and the CPDFN IRC.
Lac La Biche Community				
8-Jan-08	Lac La Biche County Mayor and Council Members	Meeting	SHC was invited to present to the Lac La Biche County Council at the SHC Open House in Lac La Biche in Oct 07. SHC President & CEO, Senior Executive VP and other executives presented. Presentation and resulting discussions with Council were very well received by both parties.	SHC will continue to inform the Lac La Biche County of further developments and updates.
25-Jun-09	Community Members, Local Officials and Local Businesses	Meeting	A significant majority of the Open House attendees were interested in employment and business opportunities afforded by the KKD Project. Some of the attendees had existing contracts with SHC, but were interested in future work. The only elected official who attended the Open House, a Lac la Biche County official, was very pleased with the Open House and SHC's proposed plans.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
Mikisew Cree First Nation				
29-Jan-08	Mikisew Cree First Nation (MCFN) IRC Regulatory Affairs Coordinator	Phone discussion	SHC contacted the IRC Regulatory Affairs Coordinator to follow-up from their meeting in November. They discussed setting up a meeting with IRC Director and SHC Senior VP representatives, possibly in mid February. IRC said they would look in to availability and respond to SHC. SHC also suggested organizing a field visit to learn more about the wildlife program/dog scat program and this is to be planned in the near future.	
1-Nov-08	IRC Regulatory Affairs Coordinator	Phone discussion	SHC representative and IRC Regulatory Affairs Coordinator planned for a meeting on November 28, 2008 for SHC to update the IRC on the SHC KKD Project and winter activities. SHC also provided IRC with an information package.	Organize field visit to provide more information regarding wildlife monitoring/scat dog program.
28-Nov-08	IRC Regulatory Affairs Coordinator; Consultation Coordinator; Environmental Affairs Coordinator	Meeting	SHC representative met with IRC representatives to provide and update relating to the current SHC KKD Project and winter activities for 2008/2009.	
1-Dec-08	GIR Regulatory Affairs Coordinator	Email	SHC emailed GIR to thank them for taking the time to meet the previous Friday afternoon. As discussed, SHC would send more information on the scat dog program and any other information about the KKD Project that may not have been included in the package. SHC will wait for information that was to be sent regarding the GRC (IRC) and possible future meeting dates.	provide info regarding scat dog program
8-Dec-08	GIR Regulatory Affairs Coordinator	Phone discussion	SHC rep contacted GIR Regulatory Affairs Coordinator to follow up from the previous meeting but GIR Regulatory Affairs Coordinator to be on vacation for one months time.	
30-Apr-09	GIR Regulatory Affairs Coordinator	email	Email requesting a follow-up meeting on SHC's KKD Project.	

Table 7-1 Kai Kos Dehseh Consultation Update

DATE	COMMUNITY PARTICIPANTS	MEETING/EVENT	OUTCOMES	FOLLOW-UP
14-May-09	GIR Regulatory Affairs Coordinator	Phone discussion	GIR contacted SHC to inquire when the IRC can meet with SHC to receive an update on the KKD Project and review the file. SHC to set a date with Mikisew.	
10-Jun-09	IRC Regulatory Affairs Coordinator; Consultation Coordinator; Environmental Affairs Coordinator	Meeting, MCFN Fort McMurray office	Meeting to discuss KKD Project. A range of issues were discussed, including the scat dog program, MSES review of the EIA, cumulative effects, land use issues, health and regional monitoring. MCFN indicated that they are seeking a moratorium on all oilsands development. MCFN requested a follow-up meeting, and further consultation if necessary after a review of available information. A copy of the EIA (and SIRs), disclosure document, and further information on the scat dog program was provided to MCFN post-meeting.	

ENVIRONMENTAL IMPACT ASSESSMENT
G. TERRESTRIAL WILDLIFE
8) **SIR 41, Page 74-79, Figures 41-4, 41-5, 41-6, 41-7, 41-8, 41-9.**
StatoilHydro indicates that additional wildlife surveys have been conducted in the Local Study Area (LSA) and Regional Study Area (RSA) since submission of the Environmental Impact Assessment (EIA).

> **a. Provide a summary of results of the surveys conducted for breeding birds, owls, snowtracking, amphibians and any other additional wildlife or vegetation surveys that have been completed in the project area since the submission of the EIA.**

RESPONSE

Surveys for winter tracking, owls, breeding birds, and amphibians were conducted for the EIA and results were provided with the Application in 2007. To further enhance the datasets provided by these surveys, information from within the RSA has also been included. All sites surveyed to March 2009 (including 2009 winter tracking) are identified in SIR(2) #41(a). Survey points established for the amphibian survey and breeding bird survey conducted in June 2009 are provided in SIR(3) #10(b) below. Survey methods are described in the EIA, Volume 4, Section 11.4.1and response to SIR(3) #10(b) below. This response provides the results of the wildlife and vegetation surveys conducted since the EIA was submitted and includes results of the surveys conducted to end of June 2009 (i.e., amphibian and breeding bird surveys).

Winter Tracking
A total of 431 km of tracking data has been included in the following assessment. Of the 431 km of data, 141 km were completed within the LSA and 290 km within the RSA (Figure 41-1, SIR(2) #41(a)).

A total of 12 species or species groups (e.g., grouse and deer) were detected in the LSA (Table 8-1). The highest species diversity was recorded in the h1 (11 species), c1 (10 species) and g1 (10 species) ecosite phases. The lowest species diversity was detected in the b2 (2 species), d3 (2 species) and b3 (3 species) ecosite phases. A total of 14 species or species groups (e.g., grouse and deer) were detected in the region (Table 8-2). The highest species diversity was recorded in the closed white spruce habitat types (Sleep 2003), which all had 13 species occurrences. The lowest species diversity was detected in the mixed grassland (4 species) and closed upland shrub (5 species) habitat types.

Table 8-1 Mean Track Densities for Each Wildlife Species or Group by Ecosite Phase in the LSA

Track Densities (tracks/km/d)												
Ecosite Phase	Grouse	Red Squirrel	Snowshoe Hare	Mink	Fisher/ Marten	Fox	Lynx	Coyote	Wolf	Deer	Moose	Caribou
a1	1.1 ±0.6	2.1 ±0.6	17.1 ±3.9								0.2±0.1	
b1	0.5 ±0.1	2.1 ±0.4	29.4±2.6				0.03 ±0.03			1.2±0.3	0.3±0.1	
b2		1.5 ±0.7	15.5±4.0									
b3		0.6 ±0.6	22.8 ±11.2				0.6 ±0.6					
b4												
c1	0.5±0.2	3.6 ±0.5	42.0±2.1		0.009 ±0.009		0.1 ±0.04	0.01 ±0.01	0.01 ±0.01	0.2±0.09	0.2±0.07	0.07 ±0.04
d1	0.02 ±0.02	1.4 ±0.3	10.0±1.8						0.05 ±0.03	0.9±0.3	0.2±0.1	0.08 ±0.08
d2	0.1 ±0.08	1.4 ±0.8	13.7±2.8		0.4 ±0.2		0.05 ±0.05				1.2±0.6	
d3		3.2 ±2.6	4.4±4.4									
e1	2.5±0.9	0.6±0.6	3.6±2.1		0.2 ±0.2		0.2 ±0.2		0.2 ±0.2	0.2 ±0.2		
f3												
g1	0.2±0.1	2.1 ±0.3	20.5 ±1.8		0.2 ±0.1		0.05 ±0.03	0.06±0.03	0.01 ±0.01	0.2 ±0.1	0.3±0.1	0.02 ±0.02
h1	0.2±0.08	0.5±0.09	7.5 ±0.7		0.1 ±0.04	0.001 ±0.001	0.07 ±0.03	0.02±0.01	0.03 ±0.02	0.1 ±0.04	0.1±0.04	0.06 ±0.03
h2	0.4±0.2	0.4±0.2	16.2 ±4.6		0.1 ±0.1							
i1	2.2 ±0.9	0.5±0.2	10.5±2.2		0.1 ±0.07					1.0±0.3	0.2±0.1	0.3 ±0.2
i2	0.3 ±0.1	0.9±0.4	17.2 ±3.9	0.08 ±0.08			0.06 ±0.05	0.04±0.04		0.4±0.2	0.7±0.2	
j1	1.5 ±0.5	2.1 ±0.9	12.4 ±2.1				0.1 ±0.06		0.1 ±0.1	0.1±0.07	0.4 ±0.2	0.1 ±0.1
j2	0.3±0.3	3.0±2.3	4.6±2.2								0.3±0.3	0.7 ±0.5
j3	0.09±0.0 9	1.7±1.0	1.9±0.8						0.1 ±0.1		0.1±0.1	0.1 ±0.1
k1												
k2												
Mean	0.5 ±0.07	1.6 ±0.13	18.6 ±0.6	0.003 ±0.003	0.09 ±0.01	0.0004 ±0.0004	0.06 ±0.01	0.01 ±0.005	0.08 ±0.03	0.4 ±0.04	0.2 ±0.03	0.07 ±0.01

Table 8-2 Mean Track Densities for each Wildlife Species or Group by AGCC in the RSA

Track Densities (tracks/km/d)														
Habitat Classes	Willow Ptarmigan	Grouse	Red Squirrel	Snowshoe Hare	Mink	Fisher/ Marten	River Otter	Lynx	Fox	Coyote	Wolf	Deer	Moose	Caribou
Black Spruce Bog	0.2 ±0.14	0.4 ±0.09	2.6 ±0.2	8.3 ±0.6		0.1±0.03	0.006 ±0.006	0.03±0.01		0.1±0.03	0.07±0.02	0.2 ±0.04	0.1±0.04	0.05 ±0.01
Closed Aspen, Balsam Poplar and/or Birch	0.08 ±0.04	0.3±0.08	4.5 ±0.4	6.7 ±0.7		0.4±0.07	0.006 ±0.005	0.08±0.004		0.1±0.04	0.06±0.02	1.8 ±0.2	0.3±0.06	0.05 ±0.02
Closed Coniferous and Deciduous Cover	0.02 ±0.02	0.2±0.1	13.3±1.4	22.2 ±2.5		0.6±0.2				0.3±0.1	0.3±0.1	0.8 ±0.3	0.4±0.1	
Closed Pine	0.09 ±0.07	0.6±0.1	2.2±0.2	11.3 ±0.8		0.1 ±0.04		0.04±0.02		0.1±0.04	0.04±0.02	0.1 ±0.07	0.1±0.04	0.06±0.02
Closed Upland Shrub		0.5±0.2	2.2±0.7	0.3 ±0.2						0.09±0.06	0.04±0.04			
Closed White Spruce	0.1±0.1	0.4±0.05	3.9±0.2	15.4 ±0.6		0.1±0.02	0.006 ±0.004	0.04 ±0.01	0.0004±0.0004	0.1 ±0.02	0.08 ±0.02	0.2 ±0.05	0.2±0.03	0.07±0.02
Graminoid Wetlands	0.7±0.3	0.3±0.09	2.0±0.3	5.9 ±1.0		0.1±0.04		0.03 ±0.01		0.2 ±0.05	0.08 ±0.04	0.5 ±0.1	0.4±0.1	0.06±0.03
Open Pine	0.1 ±0.1	0.1±0.1	2.0 ±0.4	10.3 ±2.0		0.1±0.1				0.1 ±0.1	0.01 ±0.01	0.01 ±0.01	0.0.3±0.02	
Shrubby Wetlands	0.7 ±0.3	0.9±0.3	2.7±0.5	13.3 ±1.7	0.02±0.02	0.06 ±0.05		0.1 ±0.08		0.01 ±0.01	0.2 ±0.1	0. 7±0.2	0.1 ±0.1	0.1 ±0.06
Mixed Grassland		0.5±0.3				0.1 ±0.1				0.5 ±0.3		0.1 ±0.1		
Water		0.1±0.1	0.3 ±0.3	0.4±0.3										
Other-Burn		0.3 ±0.1	0.9 ±0.3	2.4 ±0.5		0.1 ±0.08		0.04±0.03		0.2 ±0.06	0.03 ±0.03	0.2 ±0.2	0.4±0.1	0.01 ±0.01
Other - Disturbance												0.3 ±0.3		
Mean	0.2 ±0.05	0.4 ±0.03	3.4 ±0.1	11.0 ±0.3	0.001 ±0.001	0.1 ±0.01	0.004 ±0.001	0.05 ±0.008	0.0001 ±0.0001	0.1 ±0.01	0.08 ±0.01	0.4 ±0.03	0.2 ±0.02	0.06 ±0.01

Three species of concern were detected in the LSA, fisher, lynx and caribou. Fisher typically occur at low densities (approximately one fisher per 12 to 19 km^2) and their annual home range sizes vary between 6.6 and 78.2 km^2 (Powell and Zielinski 1994, Raine 1983). Their preferred habitat is large tracts of coniferous and mixedwood forests with diverse prey availability and high canopy closure (Powell 1993, Powell and Zielinski 1994). The most suitable habitat is mature to climax successional stages of coniferous forests, as this provides adequate cover and potential denning sites. Marten and fisher tracks can be difficult to tell apart, as a large male marten can have a similar track size to a female fisher. Therefore marten and fisher results were combined, thus it cannot be determined with certainty that fisher were detected in the LSA or which habitats were used.

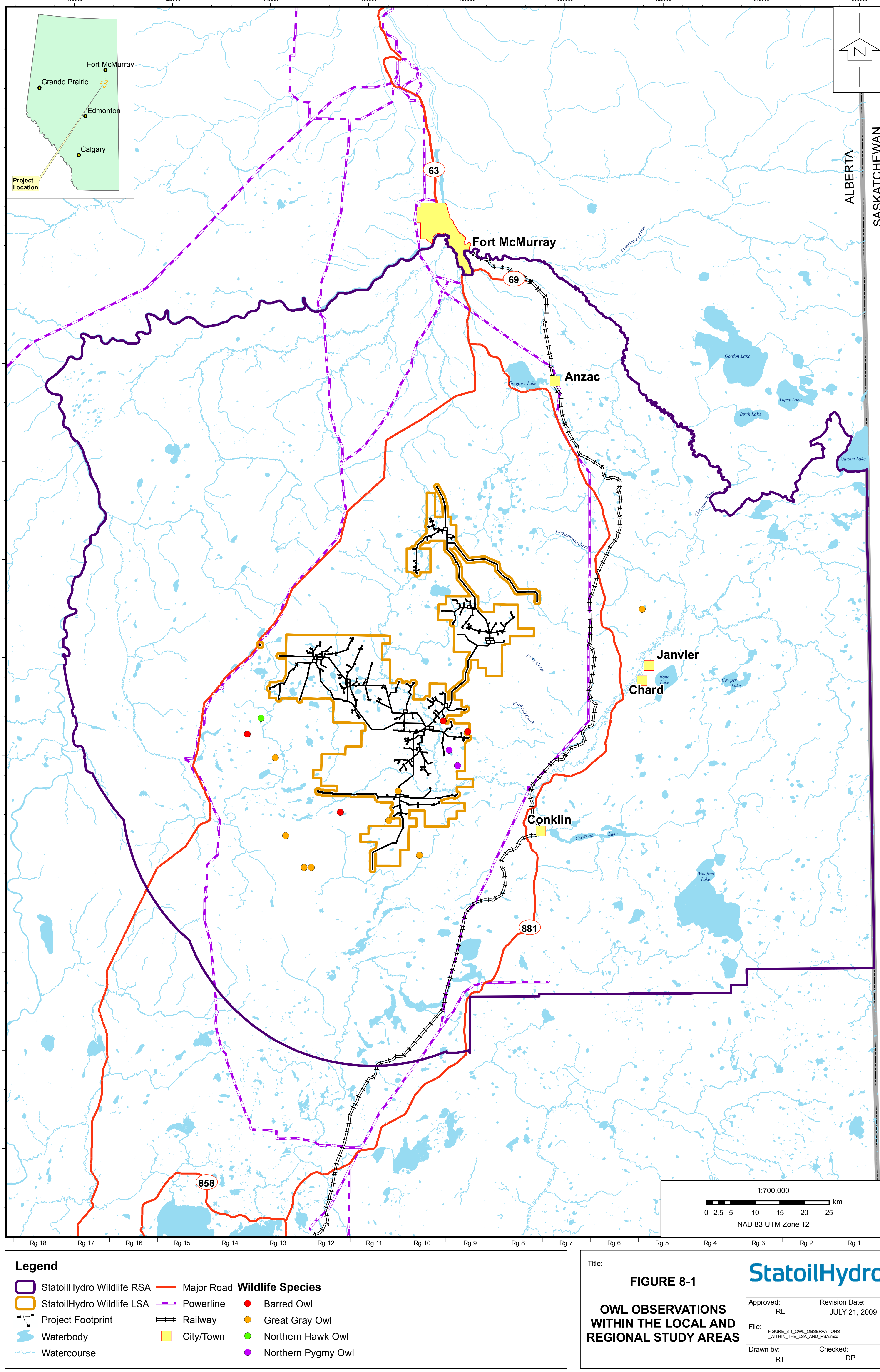
Lynx habitat use is closely linked to the distribution of their principal prey, the snowshoe hare (Brand and Keith 1979, Koehler and Aubry 1994, Mowat et al. 1999). Snowshoe hare are typically found in habitats with abundant and diverse shrub understories (McCord and Cardoza 1982). Various aged forests and structural classes are utilized by lynx; however, late successional habitats have been reported to provide important denning and security habitat, as well as thermal protection. Lynx were detected in nine ecosite phases in the LSA, with the highest mean track density occurring in the b3 ecosite phase (0.6 tracks/km/d) (Table 8-1). Lynx were detected in seven habitat types in the RSA, with the highest mean track density occurring in the shrubby wetland habitat type (0.1 tracks/km/d) (Table 8-2).

Woodland caribou in northeastern Alberta show significant preferences for bogs and fens with low to moderate tree cover (Thomas and Gray 2002), typically occupying these large wetland complexes year-round (Dzus 2001, Stuart-Smith et al. 1997). Studies in northeastern Alberta reported the use of lowland habitats by caribou in the neighbouring East Side and West Side Athabasca River herds exceeding 90% in autumn, winter, and spring (James et al. 2004). During the winter months, caribou primarily used treed or shrubby lowlands (Nexen/OPTI 2006, North American 2007), and with the exception of white spruce forests with cranberry understories, rarely used upland ecosites (North American 2007). Terrestrial lichens constitute the majority of their winter diet, although arboreal lichens are consumed when snow depths or crust makes it difficult for caribou to access terrestrial lichens (Dzus 2001, Simpson et al. 1985, Thomas et al. 1996). During the summer, the diet of caribou is more varied and aside from terrestrial lichens, they have been known to forage on shrubs, grasses, sedges, horsetails and forbs (Bergerud 1972, Boertje 1984). Caribou were detected in eight ecosite phases, with the highest density recorded in the j2 ecosite phase (0.7 tracks/km/d) (Table 8-1). Caribou were detected in seven habitat types in the RSA, with the highest density recorded in the shrubby wetland habitat type (0.1 tracks/km/d) (Table 8-2).

Owl Surveys

Five owl species were detected in the LSA including the barred owl, boreal owl, great horned owl, great gray owl and northern pygmy owl (Table 8-3, Figure 8-1). Of these, the barred owl, great gray owl and northern pygmy owl are listed as Sensitive in Alberta (ASRD 2006). Boreal owls were the most abundant species detected and were observed on six occasions during the survey. An unidentified owl was observed; however, a positive species identification could not be made since the bird was observed flying at night. Approximate locations for each owl were determined from triangulation. Ecosite phases for each observation were then determined at the triangulated locations (Table 8-3).

Eight species of owl were detected in the RSA, which includes the five detected in the LSA plus the long-eared owl, northern hawk-owl and northern saw-whet owl. (Table 8-4, Figure 8-1). Of these, the barred owl, great gray owl, northern pygmy owl, and northern hawk owl are listed as Sensitive in Alberta (ASRD 2006). The boreal owl was the most abundant species detected and accounted for over half of all owls observed. Approximate locations for each owl were determined from triangulation. Habitat types for each observation were determined at the triangulated location using GIS.



Title:

FIGURE 8-1

OWL OBSERVATIONS WITHIN THE LOCAL AND REGIONAL STUDY AREAS

StatoilHydro

Approved: RL	Revision Date: JULY 21, 2009
File: FIGURE_8-1_OWL_OBSERVATIONS_WITHIN_THE_LSA_AND_RSA.mxd	
Drawn by: RT	Checked: DP

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Table 8-3 Owl Species Observed in the LSA by Ecosite Phase

Ecosite Phase	Barred Owl	Boreal Owl	Great Gray Owl	Great Horned Owl	Northern Pygmy Owl	Unknown	Total
b2				1			1
c1	2	2					4
d2		1					1
d3					1		1
g1		1	1		1		3
h1		2		1			3
j2						1	1
Total	2	6	1	2	2	1	14

Table 8-4 Owl Species Observed in the RSA by AGCC

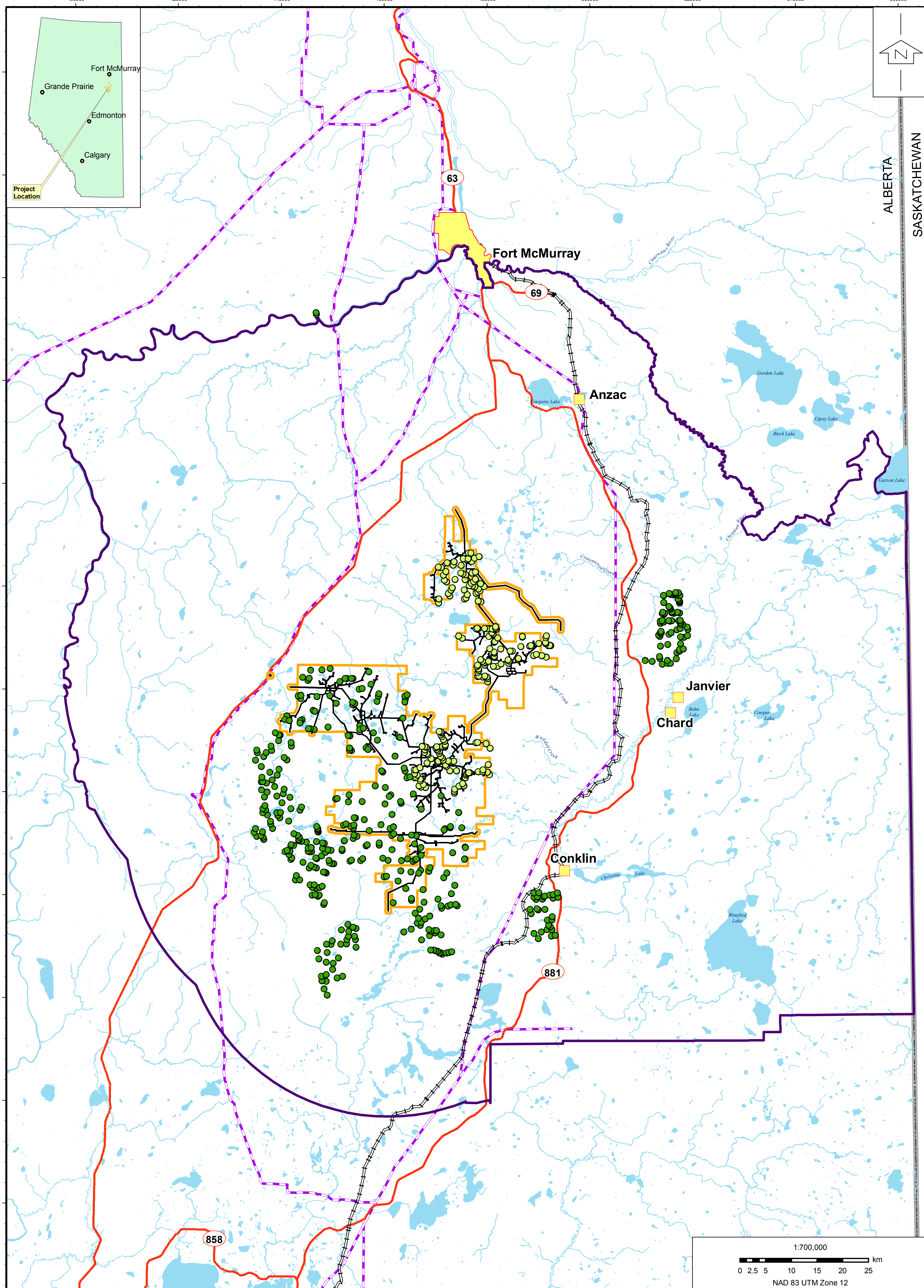
Habitat Class	Barred Owl	Boreal Owl	Great Gray Owl	Great Horned Owl	Long-eared Owl	Northern Hawk Owl	Northern Pygmy Owl	Northern Saw-Whet Owl	Total
Coniferous	2	17	3	1	1	1	1		26
Deciduous	1	8		2	1			1	14
Graminoid		11	1	3	1		1		16
Jack pine		13	2	4				2	21
Treed bog		2		3				1	6
Unknown	2	16	2	4				2	26
Total	5	67	8	17	3	1	2	6	109

Breeding Bird Surveys

Breeding Bird Density Among Habitat Types

A total of 231 point counts were established during 2006 and 2009 breeding bird surveys conducted in the LSA (Figure 8-2). Fifty-seven songbird species (68 total bird species) were observed in 21 different ecosite phases and the shrubby riparian (SR) habitat type. Several sites were completed in ecosite phases which have been burned by the House River fire. Analysis was completed for these sites, however, due to low sample sizes, these ecosite phases have not been included in the discussion. The highest density of birds was observed in the k2 ecosite phase (254.8 territories/40 ha; Table 8-5). The f1 ecosite phase had the lowest density of birds, with 51.0 territories/40 ha. Within the generic habitat classifications, the highest density of birds was observed in the shrubby fen habitat class (372.0 territories/40 ha, Table 8-5). The graminoid fen had the lowest density of birds with 145.6.

An additional 306 points were completed in the RSA from 2006 to 2009 for a total of 587 points completed in the LSA and RSA combined (Figure 8-2). A total of 73 songbird species were detected in the RSA (115 total bird species). The highest density of birds was observed in the shrubby riparian habitat class (242.0 territories/40 ha, Table 8-5). The lowest density of birds was in the jack pine habitat class (141.4 territories/40 ha, Table 8-5).



Legend

- StatoilHydro Wildlife RSA
- StatoilHydro Wildlife LSA
- Project Footprint
- Waterbody
- Watercourse
- Major Road
- Powerline
- Railway
- City/Town
- Breeding Bird Points Completed for EIA
- Breeding Bird Points Completed Since EIA Submission

Title:

FIGURE 8-2

BREEDING BIRD SURVEY POINTS WITHIN THE LOCAL AND REGIONAL STUDY AREAS

StatoilHydro

Approved: RL	Revision Date: July 23, 2009
File: FIGURE_8-2_BREEDING_BIRD_SURVEY_POINTS_WITHIN_THE_LSA_AND_RSA.mxd	
Drawn by: RT	Checked: DP

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Table 8-5 Density and Diversity Index of Birds in the LSA and RSA

Habitat Class	Ecosite Phase	Density/terr/40 ha (LSA)		Density/terr/40 ha (RSA)	Diversity Index (LSA)		Diversity Index (RSA)
		Ecosite Phase	Habitat Class	Habitat Class	Ecosite Phase	Habitat Class	Habitat Class
Jack pine	a1	203.8	203.8	141.4	2.8	2.8	24.5
Coniferous	c1	76.4	156.8	147.0	4.0	2.0	26.9
	d3	191.1			6.4		
	e3	152.9			3.0		
	g1	156.8			10.0		
	h1	131.6			10.8		
Deciduous	b2	101.9	210.9	202.0	2.0	18.1	27.4
	d1	221.5			14.3		
	e1	203.8			4.0		
	f1	51.0			1.0		
Mixedwood	b1	131.0	191.1	188.5	7.3	17.2	25.9
	b3	152.9			6.0		
	d2	158.0			12.5		
	e2	203.8			2.8		
Treed black spruce	i1	115.5	211.1	154.5	10.8	13.7	22.3
	j1	182.6			8.1		
Shrubby black spruce	i2	178.3	200.8	150.0	9.7	14.7	17.1
	j2	135.9			6.7		
Treed fen	k1	180.0	292.1	174.1	11.1	14.7	9.3
Shrubby fen	k2	254.8	372.0	197.5	20.4	21.2	13.6
Graminoid	k3	131.0	145.6	158.4	9.0	10.0	22.8
Shrubby Riparian	SR	237.8	237.8	242.0	13.9	13.9	10.6
Other (clearcut, burn)	disturbance	N/C	N/C	203.8	N/C	N/C	15.1
	burn	N/C	N/C	175.8	N/C	N/C	18.3
	clearcut	152.9	340.6	458.6	3.0	14.3	3.7
	a1-burn	229.3		229.3	4.6		4.6
	b1-burn	280.3		280.3	5.9		5.9
	c1-burn	224.2		224.2	8.3		8.3
	d1-burn	320.0		320.0	5.7		5.7
	d2-burn	101.9		101.9	2.0		2.0
	e1-burn	254.8		254.8	1.8		1.8
	g1-burn	51.0		51.0	2.0		2.0
	h1-burn	152.9		152.9	3.0		3.0
	j1-burn	101.9		101.9	2.0		2.0
	SR-burn	254.8		254.8	3.8		3.8

Within the LSA, the average individual species density ranged from 0.2 to 18.3 territories/40 ha (Table 8-6). The five species with the highest average densities included:

- yellow-rumped warbler (18.3 territories/40 ha)
- dark-eyed junco (17.0 territories/40 ha)
- chipping sparrow (12.8 territories/40 ha)
- ruby-crowned kinglet (11.2 territories/40 ha)
- Lincoln's sparrow (9.0 territories/40 ha)

Within the RSA, the average individual species density ranged from 0.1 to 13.6 territories/40 ha (Table 8-7). The five species with the highest average densities included:

- yellow-rumped warbler (13.6 territories/40 ha)
- dark-eyed junco (12.5 territories/40 ha)
- chipping sparrow (12.0 territories/40 ha)
- Tennessee warbler (10.8 territories/40 ha)
- white-throated sparrow (9.6 territories/40 ha)

Breeding Bird Diversity and Species Composition

Breeding bird diversity within ecosite phases was determined for the LSA dataset only. Diversity was highest in the k2 (20.4), d1 (14.3) and d2 (12.5) ecosite phases (Table 8-5). The lowest diversities in the LSA were recorded in the f1 (1.0) and b2 (2.0) ecosite phases (Table 8-5), however, sampling intensity was low in these sites.

Breeding bird diversity was determined within habitat associations for both the LSA and RSA dataset. In the LSA, diversity was highest in the shrubby fen (21.2), deciduous (18.1), and mixedwood (17.2) habitat associations (Table 8-5). Diversity was lowest in the coniferous (2.0) and jack pine (2.8) habitat associations. In the RSA, diversity was highest in the deciduous (27.4) and coniferous (26.9) habitat associations. Diversity was lowest in shrubby riparian (10.6) and treed fen (9.3) habitat associations.

Nine species identified as species of concern were detected during the breeding bird surveys in the LSA including:

- Yellow-bellied flycatcher (1.3 territories/40 ha, ecosite phases b3, c1-burn, i1, i2, and k3), detected on six occasions in the LSA;
- Least flycatcher (1.5 territories/40 ha, ecosite phases a1, c1-burn, d1-burn, g1, h1, i1, k2, and SR), detected on nine occasions in the LSA;
- Barn swallow (0.2 territories/40 ha, ecosite phase k1), detected on one occasion in the LSA;
- Brown creeper (1.8 territories/40 ha, ecosite phases b1, d1, d2, d3 and i1), detected on six occasions in the LSA;
- Cape May warbler (0.2 territories/40 ha, ecosite phase d2), detected on one occasion in the LSA;
- Bay-breasted warbler (0.7 territories/40 ha, ecosite phases d2 and d3), detected on two occasions in the LSA;
- Common yellowthroat (2.9 territories/40 ha, ecosite phases d3, e3, i1, j2, k2, and SR), detected on thirteen occasions in the LSA;
- Western tanager (0.2 territories/40 ha, ecosite phases h1 and SR), detected on two occasions in the LSA; and,
- Baltimore oriole (0.2 territories/40 ha, ecosite phase SR), detected on one occasion in the LSA.

Table 8-6 Bird Species Density in the LSA

SPECIES	DENSITY	SPECIES	DENSITY
Alder Flycatcher	4.6	Northern Waterthrush	0.2
American Redstart	0.4	Olive-sided Flycatcher	1.1
Baltimore Oriole	0.2	Orange-crowned Warbler	4.0
Barn Swallow	0.2	Ovenbird	6.2
Bay-breasted Warbler	0.7	Palm Warbler	7.1
Black and White Warbler	1.1	Philidelphia Vireo	2.4
Black-capped Chickadee	0.2	Pine Siskin	0.4
Blue-headed Vireo	1.8	Red-breasted Nuthatch	0.2
Boreal Chickadee	2.2	Red-eyed Vireo	1.1
Brewer's Blackbird	0.4	Rose-breasted Grosbeak	0.9
Brown Creeper	1.8	Ruby-crowned Kinglet	11.2
Cape May Warbler	0.2	Savannah Sparrow	1.3
Cedar Waxwing	1.5	Sharp-tailed Sparrow	0.2
Chipping Sparrow	12.8	Song Sparrow	0.2
Clay-colored Sparrow	1.1	Swainson's Thrush	1.3
Common Snipe	0.7	Swamp Sparrow	2.9
Common Yellowthroat	2.9	Tennessee Warbler	8.4
Connecticut Warbler	1.1	Tree Swallow	1.5
Dark-eyed Junco	17.0	Vesper Sparrow	0.4
Golden-crowned Kinglet	0.7	Warbling Vireo	0.2
Gray Jay	8.4	Western Tanager	0.2
Hermit Thrush	4.4	Western Wood-Pewee	0.9
Le Conte's Sparrow	1.1	White-throated Sparrow	4.9
Least Flycatcher	1.5	Wilson's Warbler	0.9
Lincoln's Sparrow	9.0	Winter Wren	0.9
Magnolia Warbler	1.5	Yellow-bellied Flycatcher	1.3
Mourning Warbler	0.2	Yellow-rumped Warbler	18.3

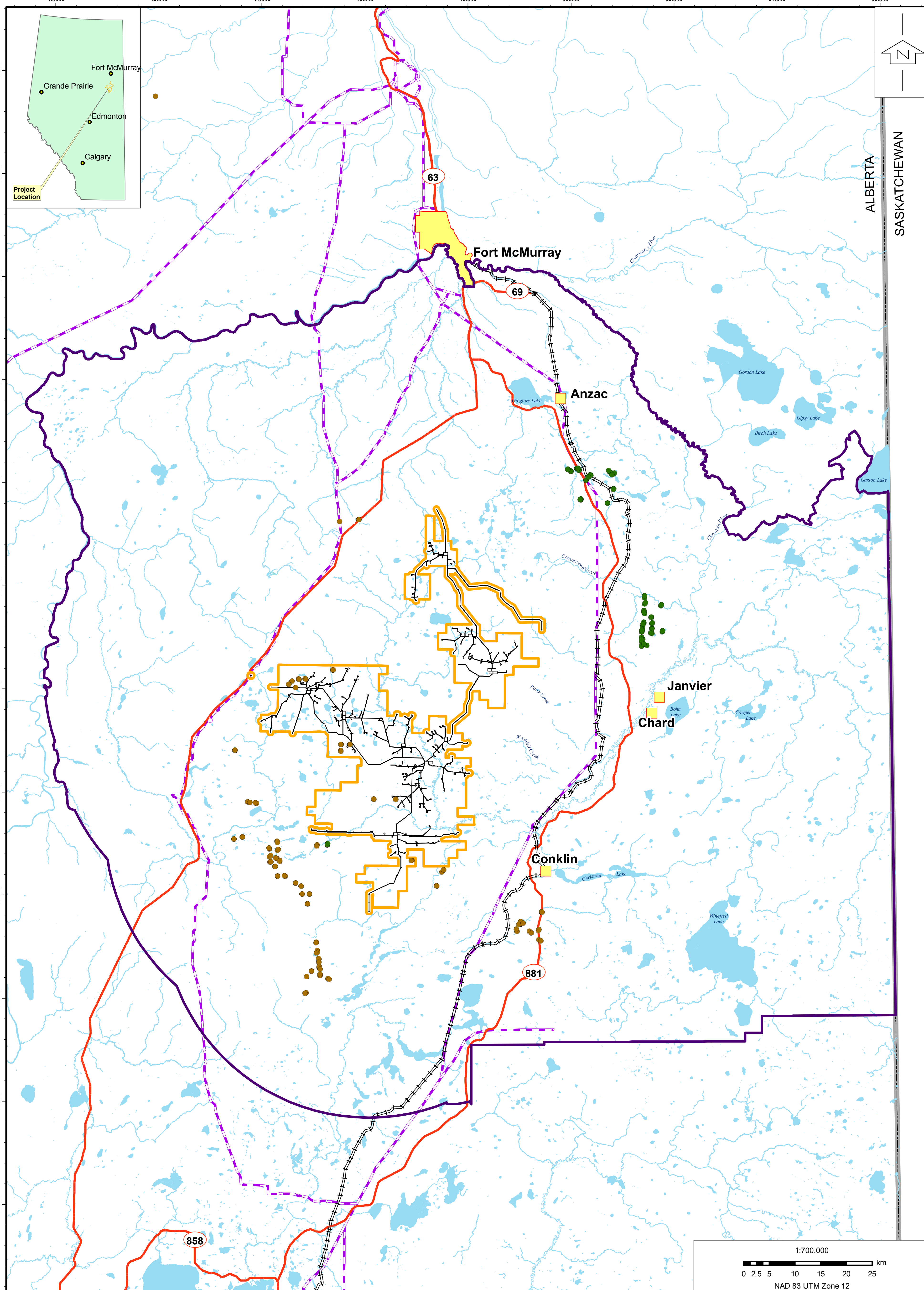
Table 8-7 Bird Species Density in the RSA

SPECIES	DENSITY	SPECIES	DENSITY
Alder Flycatcher	8.9	Marsh Wren	0.2
American Redstart	1.2	Mountain Bluebird	0.2
American Robin	1.0	Mourning Warbler	0.9
American Tree Sparrow	0.2	Northern Waterthrush	0.3
Baltimore Oriole	0.2	Olive-sided Flycatcher	1.5
Barn Swallow	0.1	Orange-crowned Warbler	3.0
Bay-breasted Warbler	0.8	Ovenbird	6.8
Black and White Warbler	1.4	Palm Warbler	8.7
Black-capped Chickadee	1.0	Philadelphia Vireo	3.0
Blackpoll Warbler	0.3	Pine Siskin	0.8
Black-throated Green Warbler	0.1	Red Crossbill	0.1
Blue-headed Vireo	1.3	Red-breasted Nuthatch	1.5
Bohemian Waxwing	0.2	Red-eyed Vireo	2.5
Boreal Chickadee	1.7	Red-winged Blackbird	0.7
Brewer's Blackbird	0.2	Rose-breasted Grosbeak	0.9
Brown Creeper	1.5	Ruby-crowned Kinglet	4.9
Brown-headed Cowbird	0.1	Rusty Blackbird	0.3

SPECIES	DENSITY	SPECIES	DENSITY
Canada Warbler	0.3	Savannah Sparrow	0.9
Cape May Warbler	0.9	Sharp-tailed Sparrow	0.1
Cedar Waxwing	1.6	Song Sparrow	0.5
Chestnut-sided Warbler	0.1	Swainson's Thrush	4.1
Chipping Sparrow	12.0	Swamp Sparrow	3.0
Clay-colored Sparrow	2.0	Tennessee Warbler	10.8
Common Raven	0.3	Tree Swallow	1.0
Common Yellowthroat	3.4	Vesper Sparrow	0.3
Connecticut Warbler	1.0	Warbling Vireo	0.2
Dark-eyed Junco	12.5	Western Tanager	0.7
Eastern Kingbird	0.2	Western Wood- Peewee	1.5
Eastern Phoebe	0.2	White-breasted Nuthatch	0.1
Golden-crowned Kinglet	0.6	White-throated Sparrow	9.6
Gray Jay	5.5	White-winged Crossbill	1.6
Hermit Thrush	3.5	Wilson's Warbler	1.3
House Wren	0.7	Winter Wren	1.5
Le Conte's Sparrow	1.9	Yellow Warbler	0.6
Least Flycatcher	2.4	Yellow-bellied Flycatcher	1.0
Lincoln's Sparrow	7.7	Yellow-rumped Warbler	13.6
Magnolia Warbler	1.5		

Amphibian Surveys
Two frog species (boreal chorus frog and wood frog) and two toad species (western toad and Canadian toad) are expected to occur in the region. Within the LSA, a total of 183 boreal chorus frogs and 44 wood frogs were detected (Table 8-8). Within the RSA, chorus frogs were detected at 119 sites and wood frogs were detected at 11 sites (Table 8-9).

In 2006, there were no toads observed in the LSA. During the 2009 survey, a total of 14 western toads were detected at 12 locations in the LSA. No Canadian toads have been found within the LSA during any surveys. However, Canadian toads were observed within the RSA before and during the 2009 surveys, verifying that the timing of the survey was adequate. Within the RSA, western toads have been detected at 45 sites and Canadian toads have been detected at 41 sites (Figure 8-3).



Legend

- StatoilHydro Wildlife RSA
- StatoilHydro Wildlife LSA
- Project Footprint
- Waterbody
- Watercourse
- Major Road
- Powerline
- Railway
- City/Town

Wildlife Species

- Canadian Toad
- Western Toad

Title:

FIGURE 8-3

CANADIAN TOAD AND WESTERN TOAD OBSERVATIONS WITHIN THE LOCAL AND REGIONAL STUDY AREAS

StatoilHydro

Approved:	Revision Date:
RL	JULY 23, 2009
File: FIGURE_8-3_CANADIAN_TOAD_AND_WESTERN_TOAD_OBSERVATIONS_WITHIN_THE_LSA_AND_RSA.mxd	
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Table 8-8 Amphibian Observations within the LSA[1]

Ecosite Phase	Boreal Chorus Frog	Wood Frog	Western Toad	Total
a1	6		2	8
b1	5			5
b3	3			3
c1	7	4	2	13
d1	16	2		18
d2	5		1	6
e1		2		2
g1	1			1
h1	36	5		41
h2	2	2	2	6
i1	11		1	12
i2	16	2		18
j1	1	6		7
Burn	11	5	1	17
Disturbance	63	16	5	84
Total	183	44	14	241

1 Amphibians were within wetlands within or adjacent to the identified habitat types.

Table 8-9 Amphibian Observations within the RSA[1]

Habitat Class	Boreal chorus frog	Wood frog	Western toad	Canadian toad	Total
Jack pine	8	1	7	1	17
Coniferous	37	5	20	2	64
Deciduous	15	1	2	4	22
Mixedwood	3	1	1	2	7
Treed black spruce	3				3
Shrubby black spruce	1		1		2
Shrubby fen	3		3	2	8
Graminoid	20	2	6	22	50
Shrubland	2		1		3
Water (NWL, NWF, NWR, WONN)				5	5
Disturbance – clearcut, burn, soil disturbance	27	1	4	3	35
Total	119	11	45	41	216

1 Amphibians were within wetlands within or adjacent to the identified habitat types.

Rare Plant and Pre-clearing Bird Surveys

Rare plant surveys were completed in 2007 and 2008 in support of the Leismer Demonstration Project, which is located within the LSA. This included surveys for the communications tower adjacent to the Leismer Demonstration CPF and the project camp location at Township 78, Range 9, W4M. These surveys were performed July 15, August 15, and 31, 2007. Additionally, in July 2008 a rare plant survey was completed for Pad L4 as an amendment to the original Pre-Development Assessment submitted to Alberta Environment (AENV). Results of this survey were submitted to AENV in November 2008.

Ecosite phases encountered during these surveys included c1, d1, d2, g1, h1/BTNN and i1 of the Lower Boreal Highlands Natural Subregion. No rare plants were observed within the proposed development footprints during these surveys. However, an occurrence of *Splachnum rubrum* (red collar moss) was observed 30 m east of the proposed Pad L4 footprint. This moss is listed as S3 by the Alberta Natural Heritage Information Center but it will not be impacted as it is well outside the area of development.

A breeding bird survey was performed on June 3, 2008 to ensure that tree clearing for the Leismer camp between June 5 and 11, 2008 would not impact migratory bird nesting. No evidence of nesting (i.e., partial nests or birds in the area carrying nesting material or food) was detected.

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b. Provide an update on the scat dog work conducted in 2008/2009.

<u>RESPONSE</u>

Between January 2008 and May 2009, the scat dog research team has made progress in three areas. First, analytical approaches for conducting DNA extraction from caribou scat, for estimating population abundance using mark-recapture analysis, and for estimating resource selection from scat locations have been developed. Second, a third winter of scat data was collected to augment the caribou, moose and wolf scat samples that were collected in the 2006 and 2007 winters. Lastly, a control area was added to the research design and was successfully sampled concurrently to sampling in the StatoilHydro leases this past winter. The control area is located near Algar Lake, located approximately 60 km northwest of the original scat dog study area and StatoilHydro leases.

The third winter of sampling was conducted from December 2008 through March 2009. Over 1800 scat samples were collected including approximately 1075 caribou, 448 moose, and 144 wolf scat. Additionally, 72 deer scat and 12 other scat from various species were incidentally collected. The sample of caribou scat collected this past winter effectively doubled from the previous sampling years. The research team adjusted their sampling design based on resource selection results from the 2006 and 2007 data; preliminary results suggest that these adjustments have lead to improvements in their ability to sample and monitor caribou and wolf populations.

To date, DNA extractions for 820 caribou, 94 moose, and 41 wolf samples have been processed. Caribou amplification efficiency has improved more than 90% since optimizing the DNA extraction protocol. Analysis of hormone data from all three species are also moving forward more efficiently than in previous years, with the caribou hormone analysis nearly complete. The research team has optimized their ability to monitor these species in this area and will have a highly accurate picture of the status for each species as analyses become completed during the remainder of 2009.

9) **SIR 41a, Page72.**
Alberta Sustainable Resource Development (ASRD) considers StatoilHydro's owl surveys to be incomplete due to inappropriate timing of surveys and lack of coverage across the entire LSA.

a. **Provide a commitment to conduct owl surveys across the entire LSA in April/March 2010.**

<u>RESPONSE</u>

StatoilHydro confirms it will conduct owl surveys across the entire LSA in April/March 2010.

As indicated in SIR(1) and SIR(2), the timing of the owl survey was endorsed by Lisa Priestley, one of the leading owl ecologists in Alberta. However, StatoilHydro is proceeding with repeating the owl survey within the Corner and Leismer areas and in the remaining parts of the LSA. The owl survey will be completed in April 2010 as requested.

b. **Provide a survey plan detailing how owl surveys will be conducted across the entire LSA.**

<u>RESPONSE</u>

The owl survey methods that will be used will follow the established survey methodology outlined in the Guidelines for Nocturnal Owl Monitoring in North America (Takats et al. 2001) and the Alberta Wildlife Animal Care Committee Class Protocol #006 (ASRD 2005). Survey stations usually located approximately 1,600 m apart, as recommended by Takats et al. (2001), to establish full coverage of a survey area and minimize the chance of surveying the same owls twice. However, due to the size of the LSA, the survey will be stratified to establish a higher density of points in forested habitat types with a structural stage 5 or greater than in shrubland and graminoid habitats since these will provide minimal nesting habitat for owl species expected to respond to call playbacks. For example, short-eared owls are not known to respond to call playback. The expected level of effort, given the size of the LSA is 50% in forested areas.

Surveys will begin one-half hour after sunset and end at approximately 0300 hours. At each station, observers will remain silent for two minutes to allow their initial disturbance to subside and to listen for owls already calling. After the initial two-minute silence, Johnny Stewart Power Pro Convert-A-Callers™ will be used to broadcast recordings of owl calls. The recordings consist of 30 seconds of calling followed by one minute of silence for each of three species of owl (boreal owl, great gray owl and barred owl). The playback will end with three minutes of silence. It is not necessary to broadcast calls of all species of owls that may be present, since it has been observed that most species will respond to various owl calls. Therefore, only the boreal owl, great gray owl, and barred owl calls will be broadcasted, in that order. The calls of the boreal owl are broadcasted first since small owl species may not call if larger owl species are calling in the area.

If an owl or owls are detected, their location will be obtained either by direct observation or through triangulation. Triangulation involves obtaining compass bearings and distance estimates to an owl from two separate locations approximately 500 m apart.

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ASRD. 2005. Alberta Wildlife Animal Care Committee Class Protocol #006: Call Playback for Owls. Available online at: http://www.srd.alberta.ca/fishwildlife/guidelinesresearch/pdf/protocol/Owl_playback_Class_Protocol_006.pdf

Takats, D.L., Francis, C.M., Holroyd, G.L., Duncan, J.R., Nazur, L.M., Cannings, R.J., Harris, W. and D. Holt. 2001. Guidelines for Nocturnal Owl Monitoring In North America. Beaverhill Bird Observatory and Bird Studies Canada, Edmonton, Alberta, p 32.

10) **SIR 41b, Page 73.**

StatoilHydro states, "*StatoilHydro proposes to conduct these surveys in the vicinity of future hubs to provide information supporting the future amendments as follows: Thornbury 2010, Hangingstone 2013, Northwest Leismer 2015, South Leismer 2026.*" Following discussions with ASRD and Alberta Environment, StatoilHydro agreed to conduct the surveys in 2009/10.

a. Provide a commitment to conduct the following surveys using appropriate survey protocols and timing (results must be submitted to ASRD within six weeks of completion of each survey):

i. Breeding bird surveys across the Thornbury area (Spring/Summer 2009);

ii. Amphibian surveys in the Thornbury and remaining South Leismer areas (Spring/Summer 2009);

iii. Bat surveys in the Thornbury area (Summer 2009).

<u>RESPONSE</u>

StatoilHydro will conduct surveys in the manner, locations and timing described in the question.

b. Provide a detailed survey plan for the above-listed surveys, including specific survey locations, timing and methodology.

RESPONSE

Breeding Bird Survey

The breeding bird survey uses a modified fixed-radius point count sampling procedure, with a detection radius of 50 m and the centre point located at least 100 m from a stand edge (British Columbia Ministry of Environment, Lands and Parks 1999). Birds are identified from the centre of the fixed radius plot by sight or sound for a period of 5 minutes. The distance to each bird, sex (if possible) and behaviour are recorded. In addition, observations of birds from 50 to 100 m and birds greater than 100 m from the point centre are also recorded. Birds seen or heard before or after the census period are recorded as incidentals.

Surveys are conducted during optimal weather conditions (minimal wind and precipitation) and during the early morning period (one half hour before sunrise to 1000 hours), which is the peak activity period for most species of birds (Bibby et al. 2000).

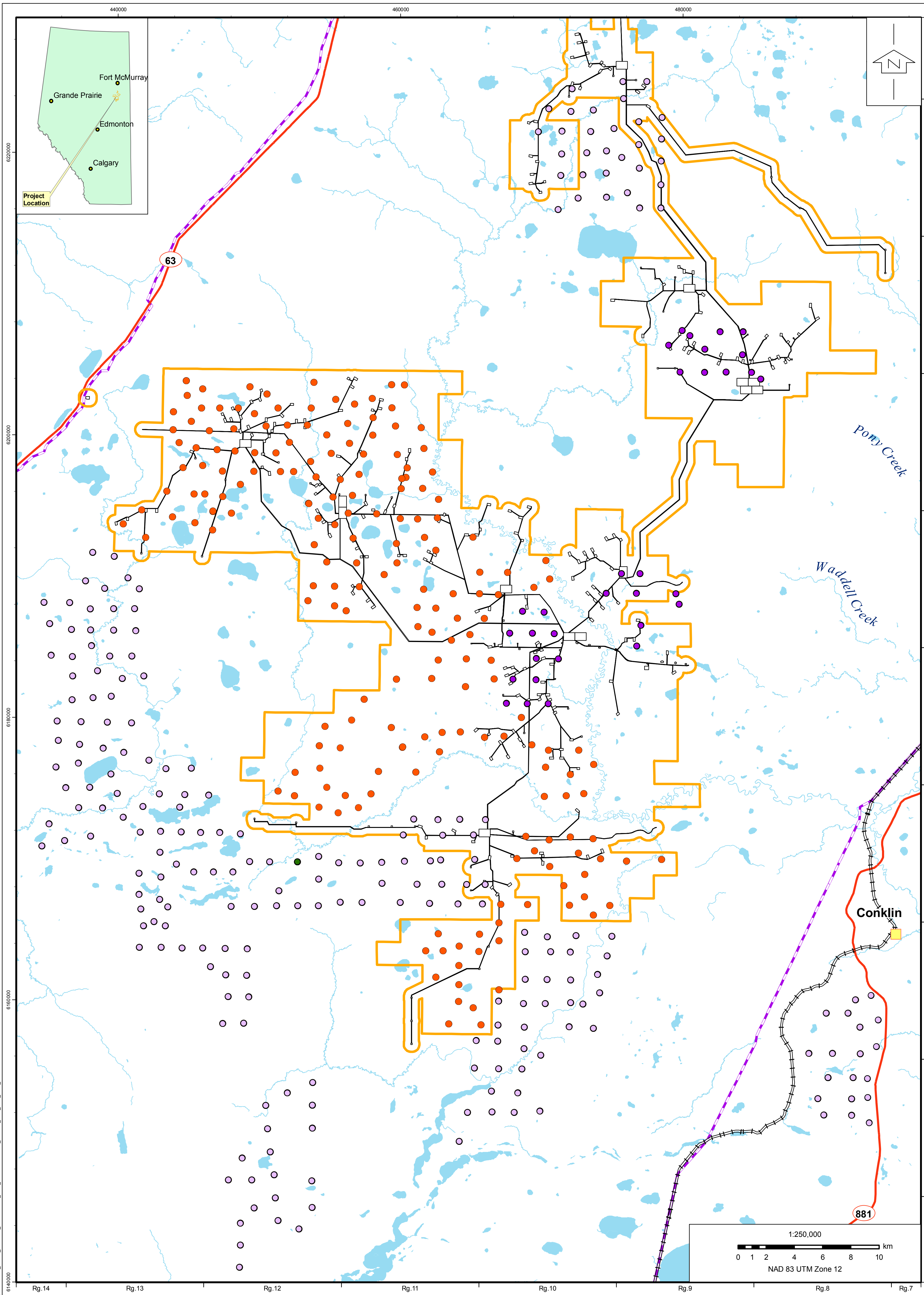
A breeding bird survey was conducted in the LSA from June 20 to 28, 2006 (see EIA, Volume 4, Section 11.4.1.5). A total of 200 point counts were established during this survey within 18 ecosite phases (Figure 8-2). As indicated in SIR(2) #41(a), breeding bird point counts within the RSA have been included for a total of 531 survey points within the LSA/RSA (Figure 8-2). As requested, a breeding bird survey has been conducted in the Thornbury and South Leismer areas of the LSA to complement the extensive data already existing within the LSA/RSA. The survey commenced on June 9, 2009 and completed on June 12, 2009. A total of 108 points were completed in this area (Figure 8-2), providing the full coverage requested by ASRD. Results of this survey are provided in SIR(3) #8(a).

Amphibian Survey

Male Canadian toads emit a loud distinct call during the breeding season which can be heard, depending on wind, cover and noise, from over 1000 m (Lauzon, personal observation). This allows for easy systematic sampling of Canadian toads over a relatively large area. This sampling methodology is used by the Alberta Amphibian Monitoring Program (ACA 2006). Sampling of specific wetlands for eggs, tadpoles or metamorphs has been suggested; however, Canadian toads will often use small un-mapped wetlands for breeding (e.g., puddles along roadside ditches or along cutlines), which makes locating suitable sites to sample very difficult. In addition, the lack of access to most wetlands would prevent collecting enough information to be of any use.

The sampling methodology focuses on the Canadian toad since this is a species of management concern in the region. However, information on wood frogs, chorus frogs, and western toads is also obtained at every survey point. Since Canadian toads emit a loud call during the breeding season, a census method similar to the owl survey is used where observers travel various access routes and establish listening points every 1000 m. However, due to the large size of the KKD LSA and limited access, sampling was stratified by high, moderate and low quality habitat as identified by the Canadian toad habitat model (see EIA, Volume 4, Appendix 11A) and therefore distance between points varies. More points were established in high quality habitat areas and fewer in low quality habitat areas.

A Canadian toad survey was conducted in portions of the LSA from June 9 to 11, 2006 (see EIA, Volume 4, Section 11.4.1.6). A total of 56 survey points were established in the LSA (Figure 10-1) with an additional 463 points surveyed in the RSA since the EIA was submitted (Figure 10-1). As requested, a Canadian toad survey was conducted in the Thornbury and South Leismer areas of the LSA. The survey was conducted June 1 to 6, 2009, and 170 points were established (Figure 10-1). This provides the full coverage as requested by ASRD. Full results of the survey are included in response to SIR(3) #8(a).



Legend

- StatoilHydro Wildlife RSA
- StatoilHydro Wildlife LSA
- Project Footprint
- Waterbody
- Watercourse
- Major Road
- Powerline
- Railway
- City/Town
- Toad Survey Locations Completed for EIA
- Toad Survey Locations Completed Since EIA Submission
- Canadian Toad Observations
- 2009 Toad Survey Location

Title:

FIGURE 10-1

CANADIAN TOAD SURVEY LOCATIONS AND OBSERVATIONS WITHIN THE LOCAL AND REGIONAL STUDY AREAS

StatoilHydro

Approved: RL	Revision Date: June 10, 2009
File: FIGURE_3-2_CANADIAN_TOAD_SURVEY_LOCATIONS_AND_OBSERVATIONS_WITHIN_THE_LSA_AND_RSA.mxd	
Drawn by: RF	Checked: RL

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Bat Survey
Several bat surveys have been conducted within the LSA from 2006 through 2008 (SIR(2), Appendix A). Two methods were used to detect bats: mist netting (physically capturing bats) and using the AnaBat II Bat Detector (identifying bats through their echolocation calls) with Compact Flash Zero Crossings Analysis Interface Module (CF ZCAIM; Titley Electronics).

Mist nets were placed at four different sites in 2006, six different sites in 2008, and two sites in the Hangingstone area along cutlines and overgrown trails between old growth forests (roosting habitat) and wet areas such as streams, bogs and marshes (foraging habitat) (Figure 10-2). To survey during peak bat activity, mist nets were set up shortly after dusk and dismantled between 0300–0515 hours (British Columbia Ministry of Environment, Lands and Parks 1998). The total mist netting effort was 127.0 (2006) and 222.2 (2008) net-hours (a single net set up for one hour equals one net-hour). The nets ranged from 1.8 to 9.1 m high and 3 to 12 m wide.

To decrease stress and the probability of injury to bats, nets were monitored constantly and bats were removed quickly after capture (CCAC 2006 website). Individual bats were placed into cloth bags and held for an hour to allow food to clear the digestive tract for a more accurate weight measurement during processing. Data collected on individual bats and net locations were based on protocols developed for bat surveys in Alberta (Vonhof 2000).

Measurements of the captured bats included species identification, sex, reproductive status, age (according to juvenile/adult characteristics), weight (using a digital scale) and forearm length (using calipers) (British Columbia Ministry of Environment, Lands and Parks 1998). Bats were released immediately following processing.

Bat detectors were used to identify bat species by their echolocation calls. Due to overlap in sonograms, some calls cannot be distinguished to species and species groups have been created (i.e., silver-haired bat/big brown bat, high frequency bat, low frequency bat, Myotis sp.). Use of the AnaBat II Bat Detector helps provide information on species that typically are not captured by mist netting, especially bats that forage high up in the forest canopy (British Columbia Ministry of Environment, Lands and Parks 1998). The bat detector is able to distinguish between foraging versus navigating activity (i.e., feeding buzzes versus navigation passes), which gives more information regarding bat behaviour at a site. An AnaBat II Bat Detector with CF ZCAIM attachment was set up in the vicinity of the nets each night to compare netting success versus activity levels recorded. Digital recording files were analyzed to determine species and activity levels at each site. To differentiate among species, all sonogram data were visualized; examination of call characteristics was necessary to differentiate similar species using AnaLook version 4.9j (Corben 2004). The minimum frequency and call slope (of the main body of the bat call) were used, along with overall call shape and pattern of calls to determine species categories. A set of criteria established by Patriquin and Barclay (2003) were used for discriminating between background noise and calls.

As requested, StatoilHydro will conduct a bat survey within the Thornbury area of the LSA. The survey will use the same methods as described above. The bat survey is planned to be conducted in early August 2009 and five survey sites are planned (Figure 10-2). Although exact locations have not yet been determined, sites along cutlines and overgrown trails between old growth forests (roosting habitat) and wet areas such as streams, bogs and marshes (foraging habitat) will be selected within the Thornbury area as delineated on Figure 10-2. In addition, bat detectors will be placed at the mist netting locations and other locations to increase sample size (Figure 10-2).

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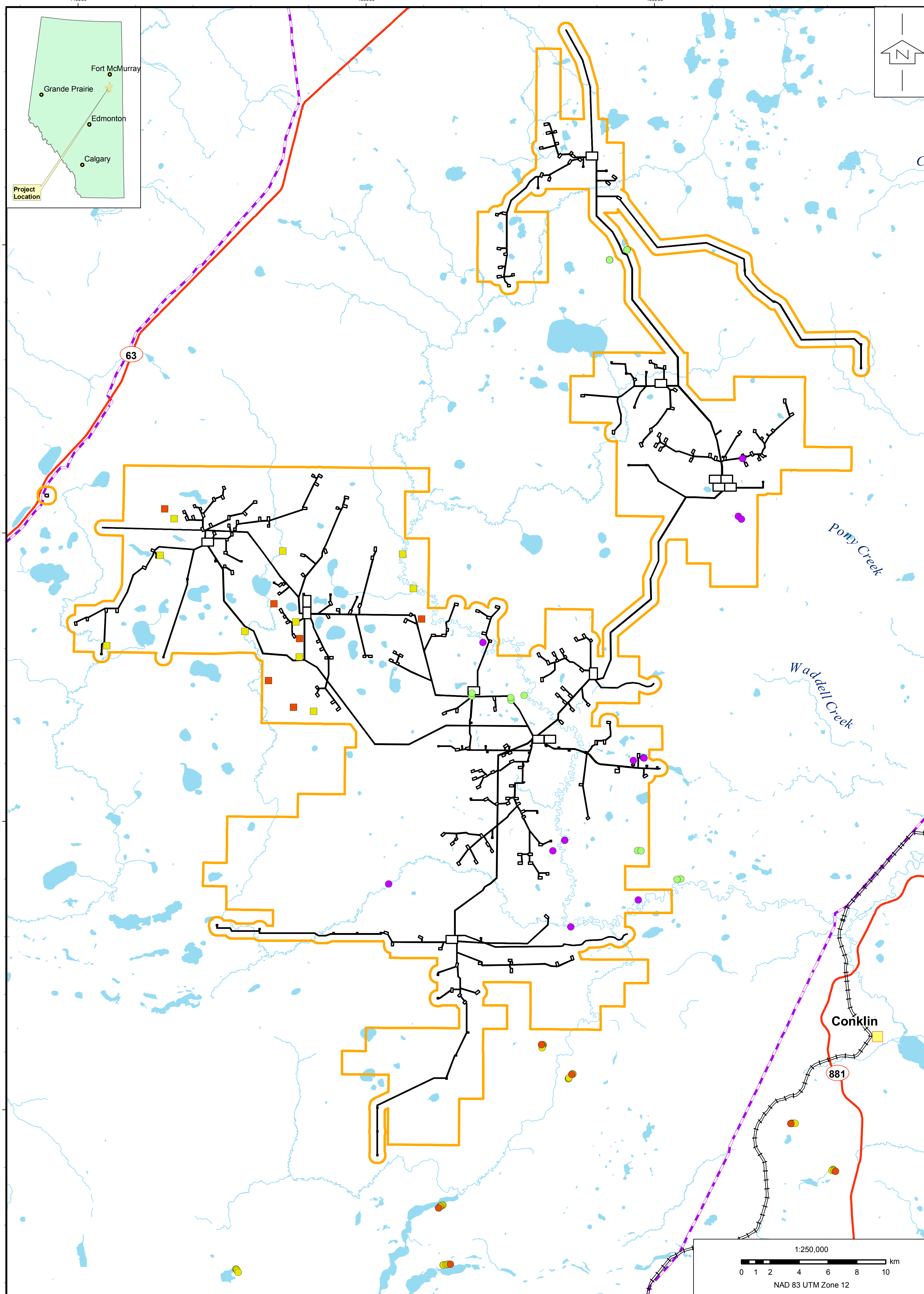

StatoilHydro Wildlife RSA
StatoilHydro Wildlife LSA
Project Footprint
Waterbody
Watercourse
Major Road
Powerline
Railway
City/Town
2006 LSA Survey Site
2008 LSA Survey Site
Regional Bat Netting Site
Regional Bat Acoustic Site
2009 LSA Bat Netting Site
2009 LSA Acoustic Site

Title:

FIGURE 10-2

BAT SURVEY LOCATIONS WITHIN THE LOCAL AND REGIONAL STUDY AREAS

StatoilHydro

Approved:	Revision Date:
RL	Sept. 22, 2009

File: FIGURE_10-2_BAT_SURVEY_LOCATIONS_WITHIN_THE_LSA_AND_RSA.mxd

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c. Clarify when StatoilHydro intends to submit an amendment application for the Thornbury Hub.

RESPONSE

As stated in the EIA Application, the schedule for the KKD Project is approximate and subject to modification in response to the receipt of regulatory approvals, business considerations and weather factors. Table 2.4-2 (EIA, Volume 1) anticipates that the application for the Thornbury hub will be submitted in 2010. The considerations previously listed may influence this date.

11) **Appendix C, Page C-4.**
StatoilHydro indicates that the Barred Owl habitat model used in its EIA was developed in the Calling Lake area. Since Resource Selection Functions (RSFs) are directly linked to the area in which they are developed, habitat types must be very similar in order for the RSF to be applied to a different area.

a. **Provide a quantitative comparison of the habitat types in the LSA and the habitat types in the Calling Lake area where the model was developed to demonstrate that the RSF is applicable to the project area**

RESPONSE

The following is a purpose and rationale for using Olsen et al.'s (2006) resource selection function (RSF) to predict barred owl habitat in the StatoilHydro LSA, including a comparison of relevant vegetation types between the two areas: StatoilHydro's LSA (LSA) and the Calling Lake study area from Olsen et al. (2006).

In the absence of an empirical model for barred owls in the LSA, the Olsen et al. (2006) RSF was applied as a best available practice. Given the model was peer-reviewed, the RSF is assumed to be sufficient with respect to barred owl biology, model fit, sample size, statistical rigor, etc. The RSF model was used in the same manner and for the same purpose in both the LSA and the Calling Lake study area. This approach is justified given the following reasons:

1. The LSA is located in the same natural region (Boreal Forest) and therefore has very similar vegetation communities as Calling Lake (Natural Regions Committee 2006). This is the basis of delineating natural regions. Although the Calling Lake study area from Olsen et al. (2006) occurs in the Central Mixedwood (CM) natural subregion, while the LSA occurs in both the CM and Lower Boreal Highlands (LBH) natural subregions, this difference has little to no effect on the RSF. First, the CM and LBH are ecologically similar and are comprised of the same group of plant species with similar community types or ecosite phases (Beckingham and Archibald 1996). Additionally, the RSF does not make its predictions based on ecosite phases, but instead uses forest characteristics (e.g., young deciduous stands, old coniferous stands, etc.) that are common between the two natural subregions.

2. All but one covariate or vegetation type in the Calling Lake RSF is also present in the LSA (Table 11-1; covariates appearing in the model are highlighted in grey). While some proportions of these habitat types are different between Calling Lake and the LSA, because selection is dependent upon the availability of resources, the proportion of individual habitat classes (resource types) in the two study areas does not need to be equivalent for the model to be valid in both locations.

Table 11-1 Areal coverage of vegetation classes in the Calling Lake study area and the LSA.

DESCRIPTION	HECTARES	
	CALLING LAKE*	STATOILHYDRO KKD LSA
Deciduous dominated stands with estimated age > 80 years	7,600	10,639
Conifer dominated stands with estimated age > 80 years	6,720	13,820
Deciduous dominated stands with estimated age ≤ 80 years	25,200	5,370
Conifer dominated stands with estimated age ≤ 80 years	1,440	2,458
Pine, includes mixed stands where pine is the dominant conifer	1,920	11,975
Black spruce bogs, includes tamarack and some birch/black spruce mixes	22,720	40,664
Other wetlands, and miscellaneous natural nonvegetated types	5,520	28,149
Water	1,680	2,775
Anthropogenic features, well sites, clearings, roads and pipelines	640	3,201
Harvested blocks < 30 yr. old	5,840	1,463
Older harvested blocks of unknown origin (> 30 yr.)	560	-
Recently burned areas	<80	4,092
Total	80,000	124,606

* Data for Calling Lake from: Olsen, B.T., S.J. Hannon and G.S. Court. 2006. Short-term response of breeding barred owls to forestry in a boreal mixedwood forest landscape. Avian Conservation and Ecology 1(3).

The one covariate that occurs in Calling Lake but not in the LSA is old harvest blocks (i.e., old clearcuts). Hence, old harvest block related habitat types will not be predicted to occur in the LSA. However, because old harvest blocks comprise less than one percent of the Calling Lake study area, they are assumed a localized and non-essential resource for barred owls in the estimated model.

3. Individual covariates in the RSF are not based on site specific attributes that may not be common between the two locations. In other words, the model is not based on specific forest conditions or vegetation species assemblages unique to the Calling Lake area. Rather, the model covariates are based on aerial proportions of habitats that are common between Calling Lake and the LSA (see Table 11-1).

4. Review of relevant literature reveals nothing suggesting that habitat use patterns by barred owls would change between the LSA relative to those in Calling Lake. Specifically, there is no evidence that:
   a. Portions of the LSA are outside of the geographic distribution of barred owls (North American 2007, Olsen 2005, Takats-Priestley 2004);
   b. Portions of the LSA are unavailable for use;
   c. Barred owl behavior differs across the boreal forest (Livezey 2007, Mazur et al. 1997, Olsen 2005, Takats 1998); and
   d. The LSA contains unique resources that would alter habitat use by barred owls (Livezey 2007, Olsen et al. 2006; see #2).

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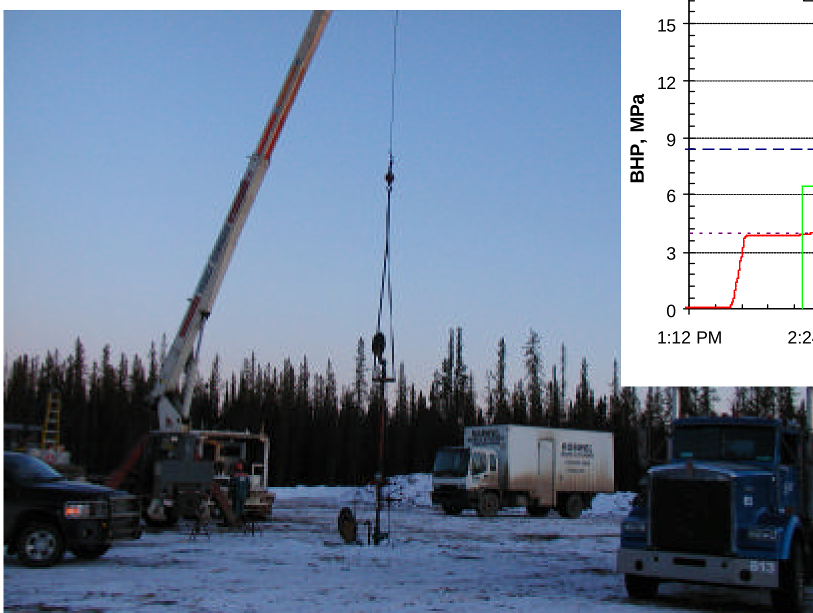
APPENDIX I.

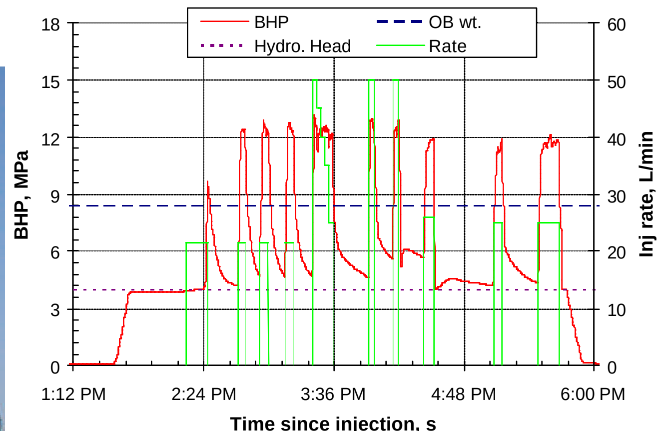
WELL INJECTION TESTS AND GEOMECHANICAL HISTORY MATCHING FOR CHARACTERIZATION OF NAOSC'S OIL SANDS RESERVOIRS

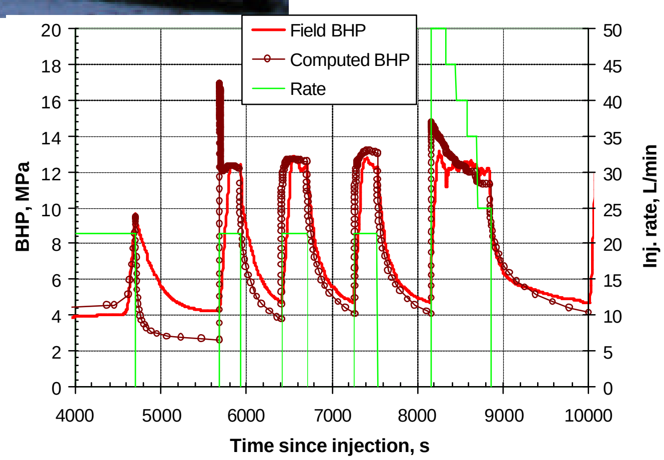
PREPARED BY BITCAN GEOSCIENCES & ENGINEERING INC.

WELL INJECTION TESTS AND GEOMECHANICAL HISTORY-MATCHING FOR CHARACTERIZATION OF NAOSC'S OIL SANDS RESERVOIRS

--- In-situ stress and geomechanical properties ---







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268 Edgebank Circle, N.W.
Calgary, Alberta T3A 4W1

BitCan 10-33
September 5, 2006

WELL INJECTION TESTS AND GEOMECHANICAL HISTORY-MATCHING FOR CHARACTERIZATION OF NAOSC'S OIL SANDS RESERVOIRS

--- IN-SITU STRESS AND GEOMECHANICAL PROPERTIES ---

Submitted to

North American Oil Sands Corporation
900, 635 8th Avenue S.W.
Calgary, Alberta T2P 3M3

by

BitCan Geosciences & Engineering Inc.
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September 5, 2006

Distribution

1 copy North American Oil Sands Corporation
1 copy BitCan Geosciences & Engineering Inc.

Prepared by:

Y. Yuan, Ph.D., P.Eng., P.Geol.
APEGGA Permit of Practice #07814

TABLE OF CONTENT

EXECUTIVE SUMMARY

Geomechanical characterization is to construct a site-specific geomechanical model. The model should include information about the original in-situ stress condition, geomechanical properties and reservoir engineering properties of the rock formation. The fluid flow-related properties are uniquely required for simulating coupled geomechanical-flow processes which are the norm in studying geomechanical effects in in-situ thermal recovery of the oil sands development. For the characterization, the current project did not repeat conventional lab tests. Instead, it conducted well injectivity tests in the field and then, history-matching in house. The well tests measured the in-situ minimum stress and provided high-quality field data for the subsequent history-matching. The history-matching derived the geomechanical model that best fits the well test data.

The current work designed and site-executed two tests. One was in the oil sands facie at 420 mTVD at well 4-27 and the other in the shaly facie at 399 mTVD at well 12-27. The recorded pressure history was first analyzed to infer about the in-situ minimum stress. Density logs were used to calculate the overburden weight which is equivalent to the vertical stress. The pressure history data were then matched using BitCan's nonlinear fully-coupled geomechanical-flow simulation models. More than 25 sensitivity cases were run and one case eventually yielded the best fit to the field data. The most appropriate mechanical and coupled flow properties were thus constrained for the reservoir intervals being tested.

Therefore, the current work has derived and verified a geomechanical model for NAOSC's reservoirs. This model is an important asset for any further works on utilizing geomechanics to enhance SAGD performance. Due to the special geomechanical properties of the oil sands reservoir materials and unique SAGD operating conditions, geomechanics can play an important role in enhancing the SAGD performance. Some applications are recommended as follows:

1. Fast start-up of the SAGD process. It targets at reducing the current start-up time in the orders of months to days.
2. Breakup of the shale stringers. We will proactively break up the permeability barriers the shale stringers constitute even when the SAGD operating pressure is relatively low.
3. Optimized SAGD operating condition: pressure and temperature. A high operating pressure may not be a necessary condition for an active geomechanical role in the SAGD process.
4. Effective implementation of single-well SAGD processes.
5. New in-situ oil sands reservoir recovery processes.

BitCan is progressing toward field trial on the fast start-up concept while moving the other initiatives through the various steps of investigation.

SUMMARY AND CONCLUSIONS

1. Transient pressure analysis of the pressure data recorded during the well injection tests suggests that the in-situ minimum stress at 399 m TVD in the shaly facie at well 12-27 to 420 mTVD in the oil sands facie at well 4-27 is all horizontal and thus, the in-situ stress regime favors a vertical fracture. The minimum horizontal stress gradient is most likely in the range of 17.8 to 19.6 kPa/m. This stress gradient range agrees with the databases BitCan compiled from various publications and own experience. Moreover, the subsequent history-matching works further fine-tuned the minimum horizontal stress gradient to 17 kPa/m.
2. The pressure data were matched reasonably well using a nonlinear fully-coupled geomechanical reservoir simulation model. BitCan vigorously derived this model in an earlier Joint Industry Project. The plastic deformation was described by a Drucker-Prager plastic model with non-associated flow rules. The elastic model was made stress-dependent and described by two parameters: Poisson's ratio and log elastic bulk modulus. The stress-dependency of flow properties including permeability was considered via a nonlinear relationship between effective water mobility and porosity. This relationship was based on multiphase flow physics and porosity change during the rock deformation.
3. Unlike majority of the well injection tests reported in the literature or executed by BitCan, tests in NAOSC's reservoirs encountered high injection pressures which are much larger than the vertical overburden weight. This was explained in the history-matching by a combination of smaller Poisson's ratio, and low friction and dilation angles. A higher fines content and/or less interlocked structure in the oil sands material may contribute to this difference[1]. Higher initial water saturation as compared to the irreducible water saturation may also play a role in causing the higher injection pressure response.
4. The well injection test in the oil sands facie at 420 mTVD at well 4-27 was matched using the following major data set: SHmin=17 kPa/m, SHmax=24 kPa/m, Sv=21 kPa/m, k=2 Darcy, Sw0=20% vs. Swc=15%, phi0=32.5%, Drucker-Prager friction angle=45º, Drucker-Prager dilation angle=35º. Please refer to the text for representations of these symbols.
5. The injection test in the shaly facie at 399 mTVD at well 12-27 was matched using in-situ stress conditions similar to the oil sands facie described in the above and following major material property data set: k=1 milli Darcy, Sw0=100%, phi0=25%, Drucker-Prager friction angle=45º, Drucker-Prager dilation angle=25º.

[1] Discussion with NOASC suggested that the less interlocked structure may be a more important factor.

RECOMMENDATIONS FOR FUTURE WORKS

The current work has delivered a site-specific geomechanical model that is verified against the field data acquired from NAOSC's reservoirs. Moreover, although it is not a part of the current deliveries, BitCan's nonlinear fully-coupled geomechanical reservoir simulation model has withstood the challenges presented by NOASC's field data and thus can be used in future geomechanical modeling. It is recommended for NAOSC to act on these deliveries/tools and continue to investigate field implementations of using geomechanical mechanisms to enhance SAGD performance.

Some example applications have been described in the "Executive Summary" and are re-iterated below for emphasis: (1) Speed up the SAGD start-up; (2) Overcome shale stringers as a permeability barrier; (3) Optimize SAGD operating pressure and temperature conditions; (4) Implement single-well SAGD processes; and (5) Innovate on other in-situ bitumen recovery processes. The fast start-up concept is progressing towards field trials by BitCan in cooperation with two major oil sands operators. BitCan is working with another oil sands player on the single-well SAGD process. BitCan has proposed a Joint Industry Project on proactively breaking up the shale stringers in the SAGD process. Funded by a major operator, a novel in-situ oil sands recovery process is being concept-tested at BitCan. We strongly recommend NOASC to join in the force in all or part of the above initiatives.

INTRODUCTION

Geomechanical characterization refers to measuring original in-situ stress condition and estimating geomechanical properties. These data fully define a geomechanical model that is essential in studying effects of geomechanics in in-situ oil sands recovery. The current work completed a cost-effective program for geomechanical characterization of NAOSC's oil sands reservoirs. It maintains that there is no need to repeat conventional lab tests and the key challenge is to conduct carefully-designed field tests and then, analyze and history-match the test data in order to obtain the site-specific geomechanical properties. We can rely on existing lab test data as a starting point. BitCan has compiled two databases covering these lab tests and in-situ stress measurements.

BitCan first designed and site-executed two well injection tests as a full-scale geomechanical field test. The test data were then analyzed for estimating the in-situ minimum stress. The pressure vs. injection rate data were history-matched to derive an appropriate geomechanical model. This report summarizes major works completed and results obtained. More detailed discussions on relevant theoretical background, design of major works, and objectives and deliverables of each major task were submitted to NAOSC in an earlier proposal or presented in various meetings with NAOSC. The following description will first cover the well injection tests and major results derived from them. It then focuses on the geomechanical history-matching and mechanical/flow properties constrained therein. Conclusions and recommendation for future works were already given at the start of this report. References, appendices, tables and figures, where applicable, are attached to the end of this report.

1. Well Injection Tests and In-situ Stress Conditions.

The injection tests were conducted at two wells, targeting at a richer oil sands facie at 420 mTVD in well 4-27 and a shaly stratum at 339 mTVD in well 12-27. A 0.5-m interval was perforated at each test target. A well log representation of the perforation interval and its surroundings for well 4-27 is shown in Figure 1. For well 12-27, there is no electronic copy of well log data and thus, a similar log cannot be shown.

Water was injected directly down into the casing. Multiple injection and shut-in cycles were used. The bottomhole pressures were monitored on-site via downhole pressure sensors. However, the injection rate was monitored and controlled by recording the stroke rate of the pump. Such manual control of the injection rate inevitably caused inaccuracy in controlling the injection such as starting-up, shutting-off and maintaining a constant rate between. This inaccuracy may propagate into affecting the following data analysis and history-matching. The injection rates used in the following analysis and plotted in the relevant figures were obtained by manually recoding the total volume pumped in each injection cycle and then dividing it by the injection period.

Towards the end of the test, the injection cycles changed to higher rates and step-rate down tests were tried to probe for possible friction involved in flow through the near-wellbore into the fracture. Similar tests are regularly used in hydraulic fracturing stimulations. However, because the injection was not metered electronically, the injection rates could not be controlled accurately. As a result, benefit of the step-rate down cycles in probing for the friction was not obvious in our tests and no detailed analysis will be carried out for these cycles.

Among the various techniques for measuring the in-situ stresses, hydraulic fracturing via controlled injection is the most reliable method. The relevant theoretical principles and interpretation techniques are described in Appendix A. In summary, interpretation of the hydraulic fracturing stress tests relies on identifying various characteristic pressures and repeating cycles to check their consistency. The characteristic pressures used in the current analysis include: (1) Instantaneous shut-in pressures (ISIP), (2) Fracture closure pressures, (3) Fracture re-opening pressure. The closure pressures were derived by 3 different plots: sqrt(dt), G and Horner plots. Details are presented in Appendix A including various characteristic pressure plots extracted from the raw data. The following analysis and description targets each injection interval respectively.

Oil sands facie at 420 mTVD in well 4-27. The BHP history recorded during the test at this interval is shown in Figure 2. The various characteristic pressures extracted from different cycles in the test are reconciled in Figure 3. The following observations can be noted:

1. Injection pressures are in the range of 15 to 20 MPa. They are much larger than the overburden weight (8.82 MPa) calculated from the density logs. Such high injection pressure response compared to the overburden weight is not commonly encountered. This suggests that NAOSC's reservoirs may possess some special geomechanical properties. It will be explained later in describing the history-matching.
2. The pressure behaviour differs between the early and late stages of the injection. In the initial 4 cycles, the fracture closure pressures from G-plots, sqrt(t)-plots and Horner plots are relatively consistent and stay below the overburden weight. However, since cycle #5, the closure pressures increase to near or significantly above the overburden weight. Moreover, as compared in Figure 4, pressure behaviour during the early stage of the injection is more reflective of fracture propagation while in the late cycles, the injection pressure is more complex. For example, in cycle #1, pressure increase became flat even though the injection continued at similar rates (Figure 4). This pressure plateau pattern agrees with typical fracture propagation behaviour. However, in late cycles such as in Cycle #9 (Figure 4), continuously increasing pressures were observed during the whole injection period. Note that cycles #1 and #9 used similar injection rates.

   We concluded that fracture was formed in the initial 4 injection cycles and therefore, the pressure behaviour is more reflective of the fracturing behaviour and its analysis to infer about the in-situ stress condition is more accurate. In the later cycles, however, the pressure behaviour is more complex and not definitive about the fracturing behaviour. Its values for being used to infer about the in-situ stress condition are limited. Consequently, in the following analysis, only the early cycles of pressure data are used to derive the in-situ minimum stress.

3. Analysis on the first 4 cycles of pressure data suggests that the in-situ minimum stress is 17.8 kPa/m at 420 mTVD (Figure 2). Thus, a vertical fracture is formed and the measured 17.8 kPa/m stress gradient is the minimum horizontal stress gradient. The theoretical background for deriving the stress gradient was described in Appendix A.

Shaly facie at 399 mTVD at well 12-27. The BHP history recorded during the test at this interval is shown in Figure 5. The various characteristic pressures extracted from different cycles in the test are summarized in Figure 6. The overburden weight shown in the plots is an estimate because there was no digital density log data for the well. Based on BitCan's experience, a vertical stress gradient at 21 kPa/m is reasonable in the region. In fact, wells 4-27 and 12-27 are close to each other. Digital well log data at well 4-27 gave a similar vertical stress gradient. Pressure plateau was observed during the injection in all the cycles at the current well 12-27. As described before, this is typical fracture propagation behaviour. Therefore, the pressure decline analysis results should better reflect the in-situ stress condition.

In cycles 5 to 8, a manual flowback period was imposed when the wellhead was opened shortly after the shut-in and closed again after a prescribed amount of volume was flushed out. The flow-back was used in order to accelerate fracture closure and observe the pressure rebounding. Similar procedures are commonly used in in-situ stress measurement in low-permeability formation. However, because of the inaccurate control on the flowing back volume and rate, the field data did not show substantial information about the pressure rebounding and therefore, its value to infer about the in-situ stress is limited and was not used herein for further analysis. The pressure decline data for these cycles that had flowing-back could not be analyzed for the various characteristic pressures.

Based on pressure decline analysis results for cycles #1-4, we estimated a minimum stress gradient at 18.6-19.6 kPa/m at 399 mTVD at well 12-27. This is still lower than the vertical stress gradient, indicating a vertical fracture is formed and the 18.6-19.6 kPa/m stress gradient is the in-situ minimum horizontal stress.

To summarize the above discussions, it is reasonable to conclude that the in-situ minimum stress at 399 m TVD in the shaly facie at well 12-27 to 420 mTVD in the oil sands facie at well 4-27 is all horizontal and thus, the in-situ stress regime favors a vertical fracture. The minimum horizontal stress gradient is most likely in the range of 17.8 to 19.6 kPa/m. This stress gradient range agrees with the databases BitCan compiled from various publications and own experience. Moreover, the following history-matching works further fine-tuned the minimum horizontal stress gradient to 17 kPa/m.

2. History-matching of well injection test in the oil sands facie at 420 mTVD at well 4-27

Figure 7 compares the simulated pressure response to the cyclic injection with the recorded field data. The agreement is generally good especially after the first 2 injection cycles. The mis-match in the first two cycles mainly occurs in the injection periods. Good match was also obtained for the pressure falloff during the shut-in of these 2 cycles. The mis-match for the injection may be due to the wellbore storage and significant near-wellbore friction.

Attempts to match pressure behaviour after cycle #7 were not made. Injection rate in Cycle #7 fluctuated greatly and error in calculating the rates becomes much larger and therefore, no value would be gained from continuing the match.

The computational model for the history-matching is shown in Figure 8. Input parameters for the simulations are summarized in Figure 9. The vertical stress gradient, Sv=21 kPa/m, was independently calculated from the density log. The maximum horizontal stress gradient, SHmax=24 kPa/m, was taken from a BitCan-compiled database. So was the formation pressure, p_0=3 MPa. The minimum horizontal stress gradient, SHmin=17 kPa/m, used for the best fit is smaller than the 17.8 kPa/m inferred from the transient pressure analysis of the injection test as described in the above. Figure 10 shows that if directly using 17.8 kPa/m in the history-matching, it was found that the match was not as good as 17 kPa/m. Therefore, it was concluded the SHmin should be fine-tuned to 17 kPa/m for the current oil sands facie.

Figure 11 lists the nearly 25 simulation runs conducted to arrive at the best-fit shown in Figure 7. The sensitivity analysis compared the effect of different sizes of models and mesh effect. Effect of mechanical properties and reservoir engineering properties was also studied. For example, as noted before, high injection pressures that are much larger than the overburden weight were observed in the current field test. Figure 12 shows that a combination of smaller Poisson's ratios and smaller friction and dilation angles can partly explain the high pressure response. Such a combination of mechanical properties may be caused by several lithological factors, e.g. a higher fines content or less significant inter-locked oil sands grain contact. Discussion with NOASC after the simulations suggested that the latter may be a more important factor.

Figure 13 demonstrates that a higher initial water saturation (Sw0) compared to the irreducible water saturation (Swc) also yields a larger computed injection pressure. It also makes the pressure decline faster during the shut-in. The higher Sw0 improves the initial water mobility as shown in Figure 14. As a result, the pressure diffuses faster and the resulting poroelastic backstress buildup is more significant.

The good history-matching as described in the above supports that the nonlinear coupled flow-deformation model used for the matching is reasonable and the relevant input parameters are appropriate. The fully-coupled nonlinear geomechanical reservoir simulation model used a Drucker-Prager plastic model with non-associated flow rules. The elastic model was made stress-dependent and described by two parameters: Poisson's ratio and log elastic bulk modulus (Figure 9). The nonlinear relationship between effective water mobility and porosity as shown in Figure 14 considered the multiphase flow physics. The coupled simulation model used in the current work was vigorously derived in a Joint Industry Project (JIP) completed by BitCan in 2002 (Yuan, 2002a and b).

As shown in Figure 15, the fracture propagation extent was not significant at the end of the 6th injection cycle and most of the fracture length was created in the 1st injection cycle. For example, after the 1st injection cycle where a cumulative fluid volume of 177 litre had been injected, the fracture propagated 0.8 m into the formation. After a cumulative 871 litre at the 6th injection cycle, the fracture extended to 1.1 m. Thus, a mere 0.3 m incremental fracture length was created after an incremental 700 litre was injected. This reflects the increased contribution of fluid leakoff. More fluid leaked into the formation due to dilation caused by the 1st injection cycle and consequently, less fluid was effective in extending the fracture thenafter.

3. History-matching of well injection test in the shaly facie at well 12-27

Figure 16 compares the simulated pressure response with the recorded field data for the test completed in the shaly facie at well 12-27. The agreement is good and remarkably, this is only the first-trial result. Figure 17 shows the computational model, in-situ stress and material properties used in the history-matching. The model was created by referring to the well logs. The in-situ stress data were similar to the ones used in matching the oil sands test described in the above except the original formation pressure was now reduced to 2.5 MPa reflecting the shaly nature of the formation. NAOSC supported this initial reservoir pressure figure. The Drucker-Prager friction angle was also inherited from the oil sands. But a smaller dilation angle was used reflecting much less abundant sand grains and more fines content in the current shaly facie. 100% water saturation was assumed. No attempts were made to match the test data after cycle #5 because flow-back was used during the shut-in since this cycle.

The SHmin=17 kPa/m used for matching the current shaly facie is smaller than the 18.6-19.6 kPa/m inferred from the transient pressure analysis of the injection test. The discrepancy may be caused by the uncertainties in the pressure transient analysis. The relatively slow fluid leakoff process in the shale makes it difficult to accurately pinpoint the fracture closure points on the pressure response.

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APPENDIX A: INTERPRETATION OF HYDRAULIC FRACTURING STRESS TESTS

This appendix will review procedures used in the industry to derive the minimum stress from pressure history acquired during the hydraulic fracturing stress tests. The tests involve injecting a small amount of low-viscosity fluid, most conveniently water, and measuring the bottomhole pressure response. As schematically shown in Figure A.1, a fracture is created and propagated during the first injection. The well is then shut-in to observe the pressure fall-off. The declining pressure eventually closes the fracture. New injection cycles re-open and then propagate the fracture further. Such repeated injection/shut-in cycles can help probe the in-situ stress component that acts perpendicular to the fracture.

The hydraulic fracturing stress tests have been routinely used as a pre-phase in hydraulic fracturing stimulations to characterize the formation to be fractured. Numerous publications exist about execution and analysis of these tests. In addition to the current appendix, interested readers are recommended to refer to a recent publication on reservoir stimulation (Economedis and Nolte, 2002) that is often freely distributed by Schlumberger to its clients.

Analysis of the hydraulic fracturing stress tests for estimating the in-situ minimum stress relies on obtaining the following characteristic pressures from the recorded pressure history during the tests.

Instantaneous shut-in pressures (ISIP): After the well is shut-in, the bottomhole pressure falls off rapidly due to disappearing friction that presents when fluid flows through the near-wellbore area into and along the fracture path. The end-point pressure of this rapid pressure declining phase is ISIP. In earlier times, it was often equated to the minimum stress that acts to close the fracture. As shown in Figure A.2, detection of the ISIP's is often made by locating the deviation point from the linear trend in the early pressure decline data plotted on Cartesian grids.

After the hydraulic fracturing is better understood, it was found that the ISIP point may not necessarily correspond to the fracture closure. This is especially true in formations having low effective mobility to the injected fluid. Meanwhile, lack of downhole shut-off valves often obscures the early pressure falloff data which makes it unreliable to pinpoint the ISIP point. Nowadays, fracture closure pressures to be described below are often used to replace the ISIP's role in estimating the minimum stress.

Fracture closure pressure: After the well is shut-in and as the fluid leaks away from the fracture into the formation, fluid pressure inside the fracture decreases and eventually reaches equilibrium with the minimum in-situ stress acting perpendicular to the fracture. At the latter point, the fracture closes and the fracture pressure is called fracture closure pressure. Hydraulic fracturing stress tests typically rely on detecting the fracture closure pressure from the recorded pressure data and equating it to the in-situ minimum stress. Several methods are used in the industry to detect the closure pressure:

Sqrt(dt)-plot: It argues that fluid leaking from the fracture into the formation is predominantly linear before the fracture closes completely. Such a linear flow regime is well-known by a linear trend on pressure vs. sqrt(dt) plots where dt is the time lapse after the shut-in as shown in Figure A.3. The end-point pressure of the linear flow regime is taken as the closure pressure (Figure A.3). Correspondingly, a log-log plot for the pressure-time history may reveal a half slope during this linear flow period, which is an additional check about the linear flow regime (Figure A.4).

G-plot: A more vigorous derivation about fluid leakoff from a hydraulically-created fracture gave rise to a concept of G-plot (Nolte, 1979). It was then extended to determine fracture closure pressure in the stress tests (Castillo, 1987). Construction of the G-plots involves some level of mathematical manipulation. Details can be found in Economedis and Nolte (2002). The end-point pressure on a linear trend of the G plot is the fracture closure pressure as shown in Figure A.5.

The G-plot is the most established pressure decline analysis procedure in hydraulic fracturing stimulations and thus, believed to be most representative of the fracture closure if the linear trend can be identified. However, when data quality is an issue, the linear segments on the G-plot may not be obvious. Moreover, all the derivations about the G-plot were based on elastic hard rock formations. Effect of significant shear-induced dilation and its nonlinear coupling to fluid flow, as it prevails in the oil sands, is not investigated in details. All these will compromise the quality in the determined closure pressures. Nevertheless, whenever the linear trend was obvious, the G-plot was used to determine the fracture closure pressures in our analyses.

Horner plot: After the fracture closes, the flow regime progresses towards radial flow. Therefore, a Horner plot, well-established in the transient pressure analysis in well testing, may be used to detect the fracture closure. The beginning-point pressure of the linear trend on a Horner plot may be equated to the fracture closure pressure. This was used by Chinna and Agar (1985) in their hydraulic fracturing stress tests in the oil sands. Figure A.6 shows an example Horner plot to detect the fracture closure pressure. When compared to other plots described in the above, the Horner plot was found to consistently give higher values for the fracture closure pressures. This may be due to the typical overlapping between different flow regimes in the transient pressure analysis. The radial flow regime shown by straight lines in Horner plots occurs earlier than the actual fracture closure.

Fracture re-opening pressure: In subsequent injection cycles after a fracture is formed, the early pressure increase is dominated by wellbore storage plus the compressibility of the porous medium being injected into. This is usually marked by a straight line in a Cartesian plot of the pressure increase vs. time as shown in Figure A.7. When the pressure buildup is sufficiently high to open up the previously created fracture, the pressure increase is substantially slowed due to the significantly-increased transmissibility from the newly-opened fracture. Therefore, the deviation point in the pressure rise during the injection from the early straight line in a Cartesian plot marks the fracture re-opening pressure that can be used to estimate the minimum in-situ stress acting perpendicular to the fracture.

The fracture re-opening pressures are generally larger than the fracture closure pressures derived from pressure decline stages of the tests. Friction involved in fluid flow through the near-wellbore region into and along the fracture is responsible. The combined deformation mode of dilation and tensile parting may also affect the difference. As described in the texts, the fracture re-opening pressures were not used to estimate the in-situ minimum stress. They were used to check on the data quality of the acquired field pressure data.

Each injection/shut-in cycle for all the tests conducted at wells 4-27 and 12-27, where quality data existed, was analyzed to determine the characteristic pressures described in the above. For reference purposes, the relevant plots are attached in Figures A.8 and A.9.

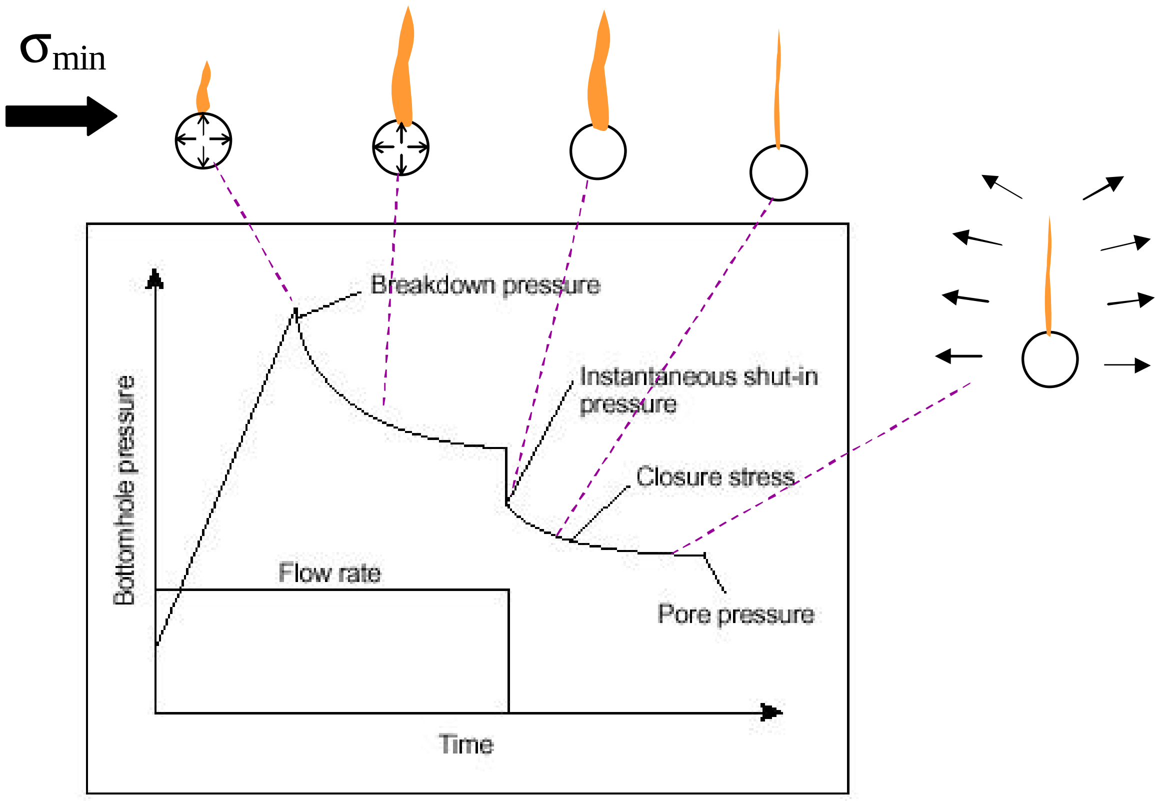


Figure A.1: A schematic showing a typical pressure-time history recorded during a hydraulic fracturing stress test and its corresponding fracturing events. The pressure-time plot is from Thiecerlin and Rogiers (2000).

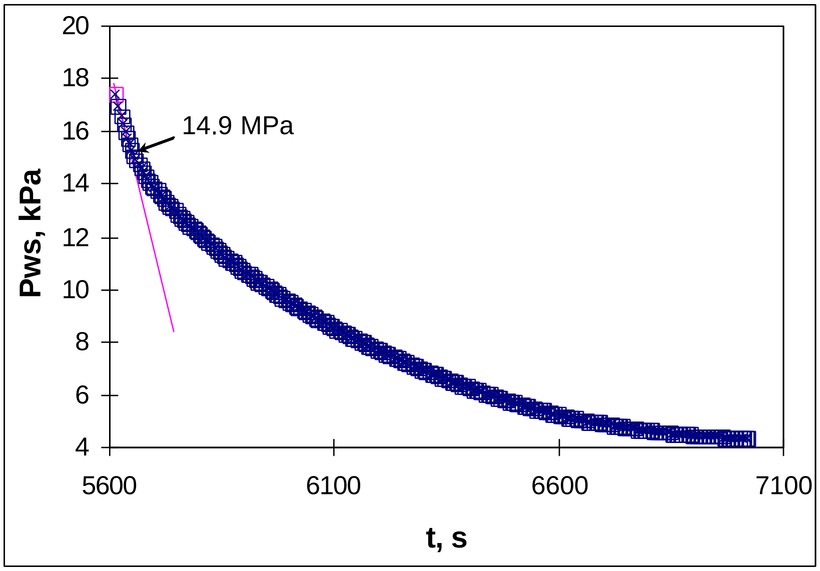


Figure A.2: An example pressure vs. time Cartesian plot aiding detection of the instantaneous shut-in pressure from the pressure decline data in a hydraulic fracturing stress test.

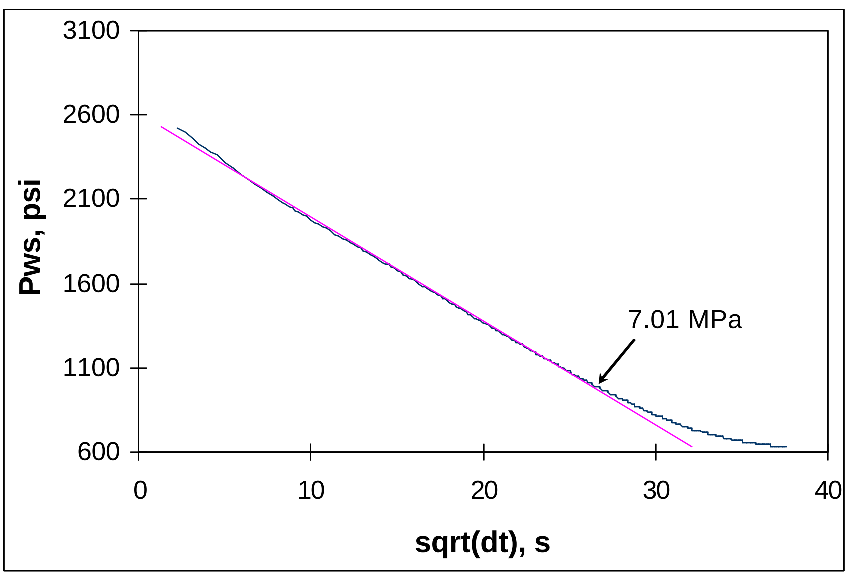


Figure A.3: An example pressure vs. sqrt(dt) plot to select the fracture closure pressure.

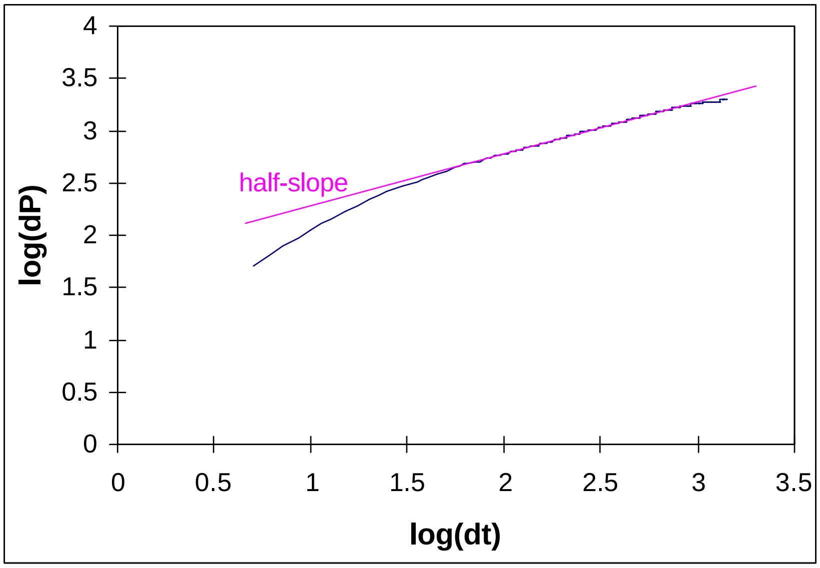


Figure A.4: When the data quality permits, a log-log plot on the pressure decline vs. time data can be used to aid selection of the linear flow regime and therefore, the fracture closure pressure.

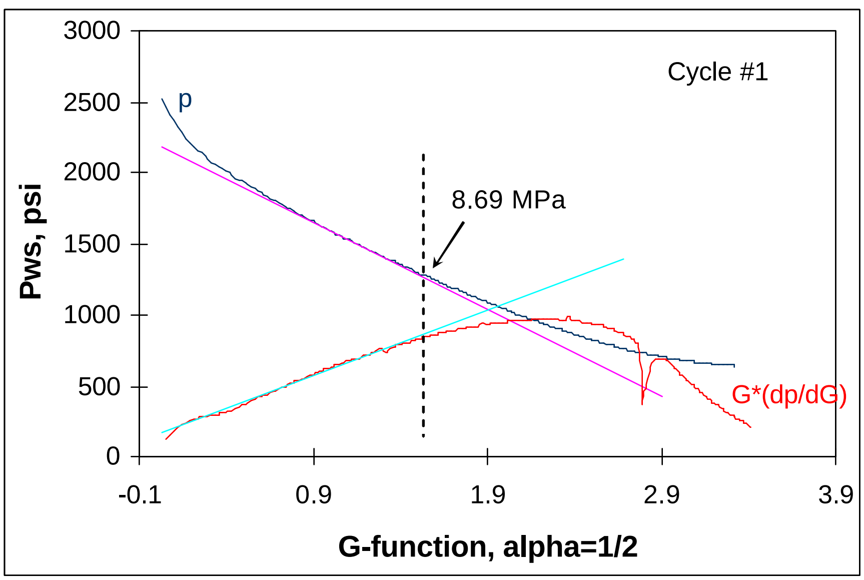


Figure A.5: An example G-plot used to determine the fracture closure pressure.

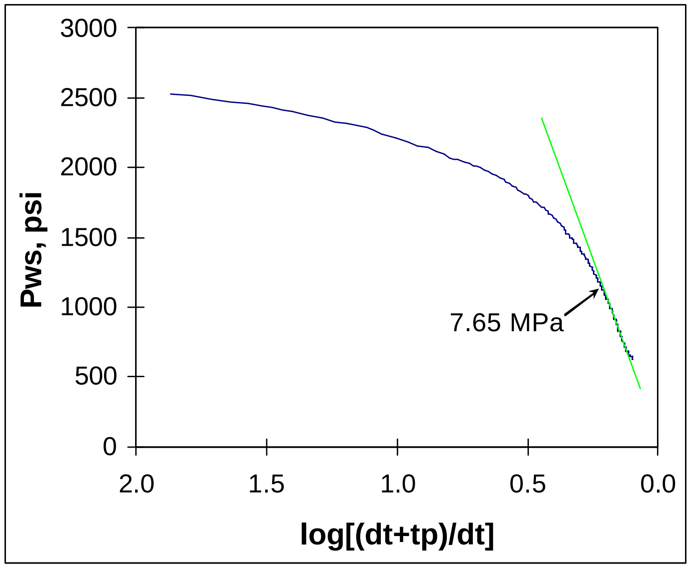


Figure A.6: An example Horner plot to determine the fracture closure pressure.

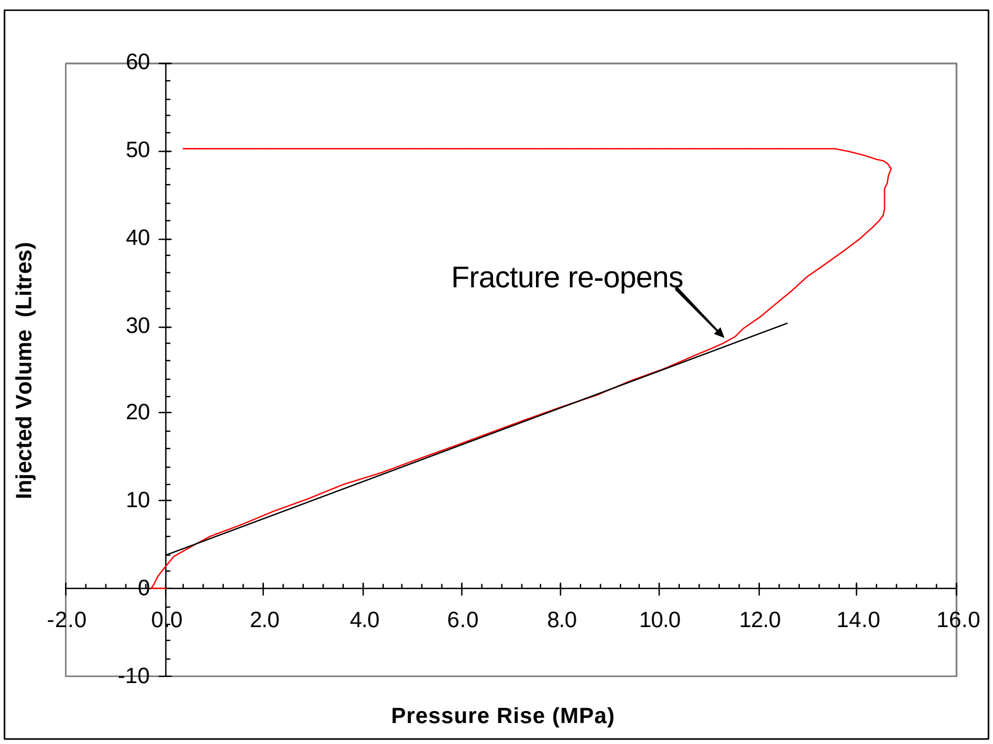


Figure A.7: An example Cartesian plot for pressure rise during the injection vs. cumulative injected volume to determine the fracture re-opening pressure.

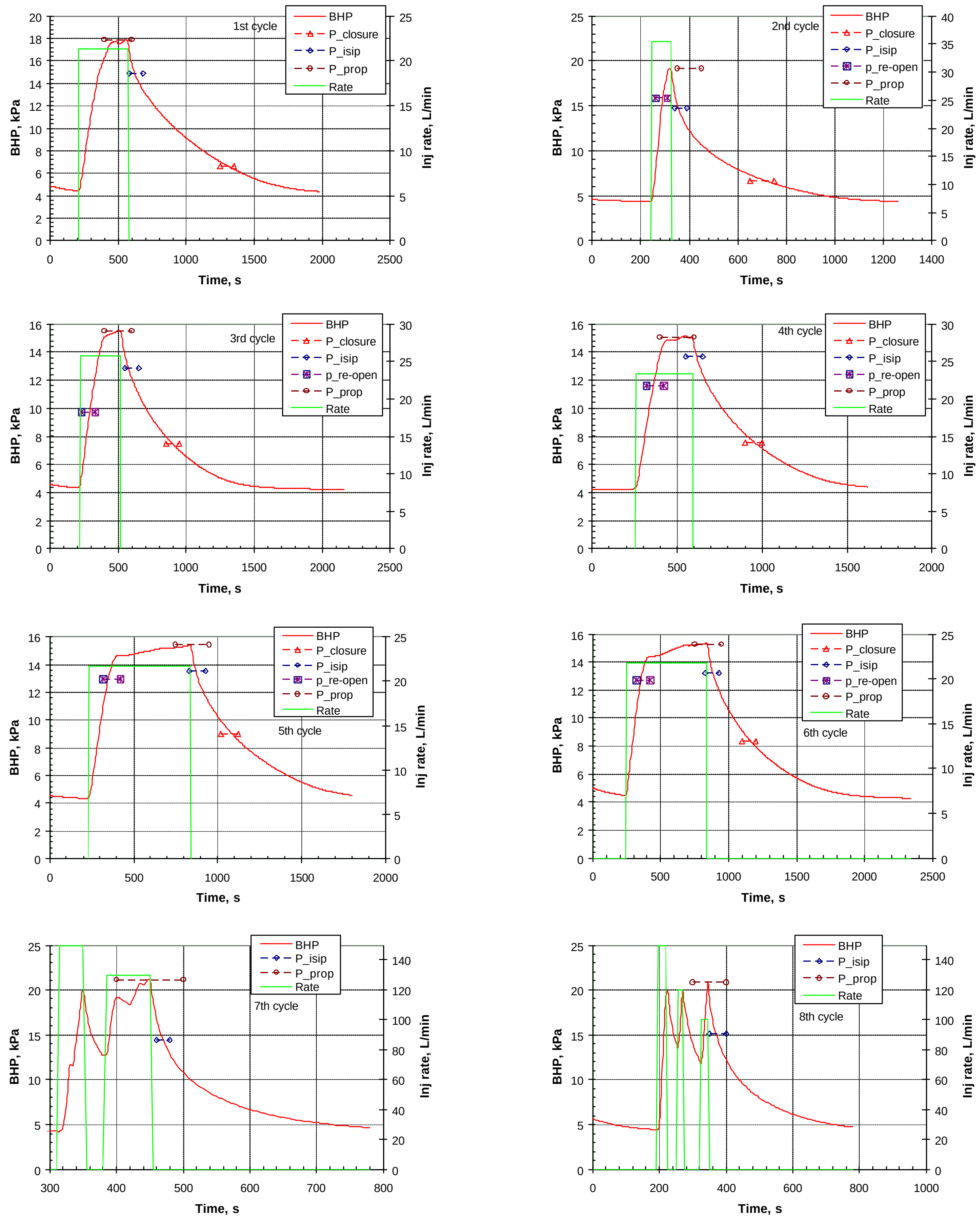


Figure A.8: Characteristic pressures determined from the various injection/shut-in cycles in testing the oil sands facie (420 mTVD) at well 4-27.

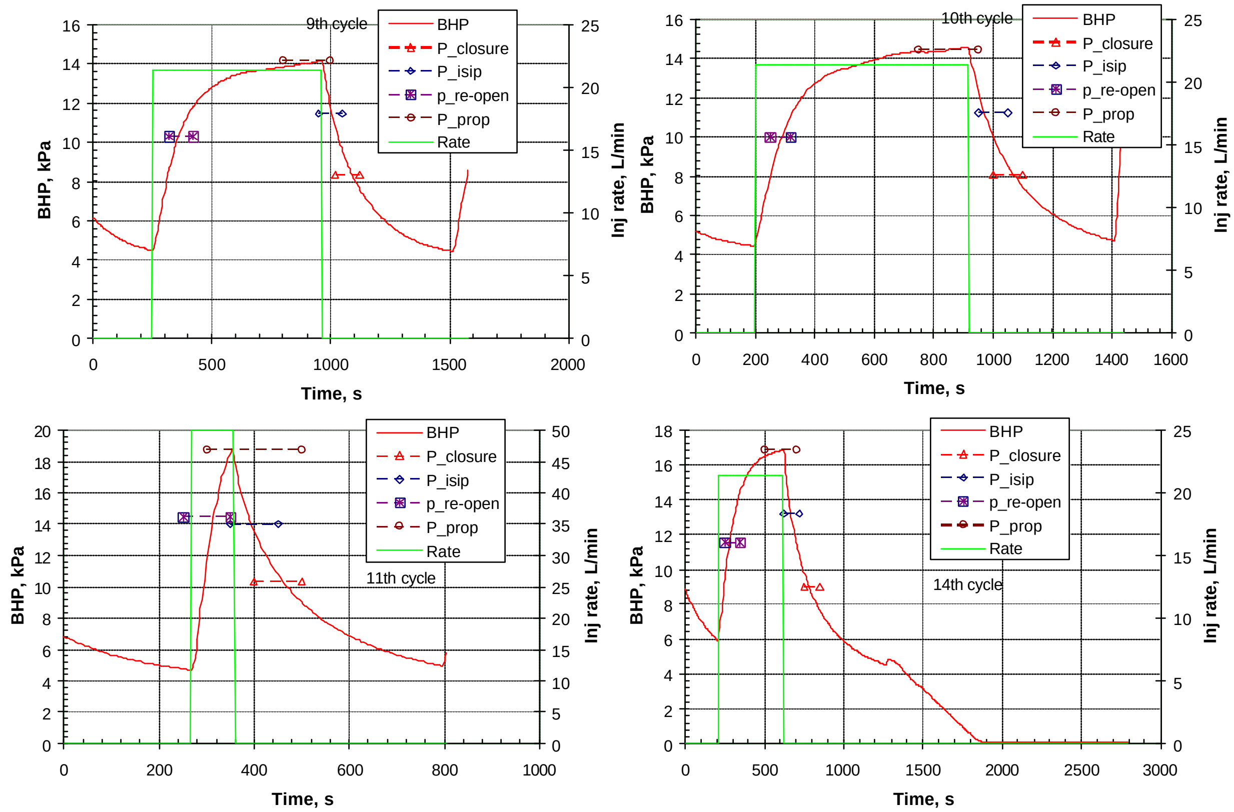


Figure A.8 (cont'd): Characteristic pressures determined from the various injection/shut-in cycles in testing the oil sands facie (420 mTVD) at well 4-27.

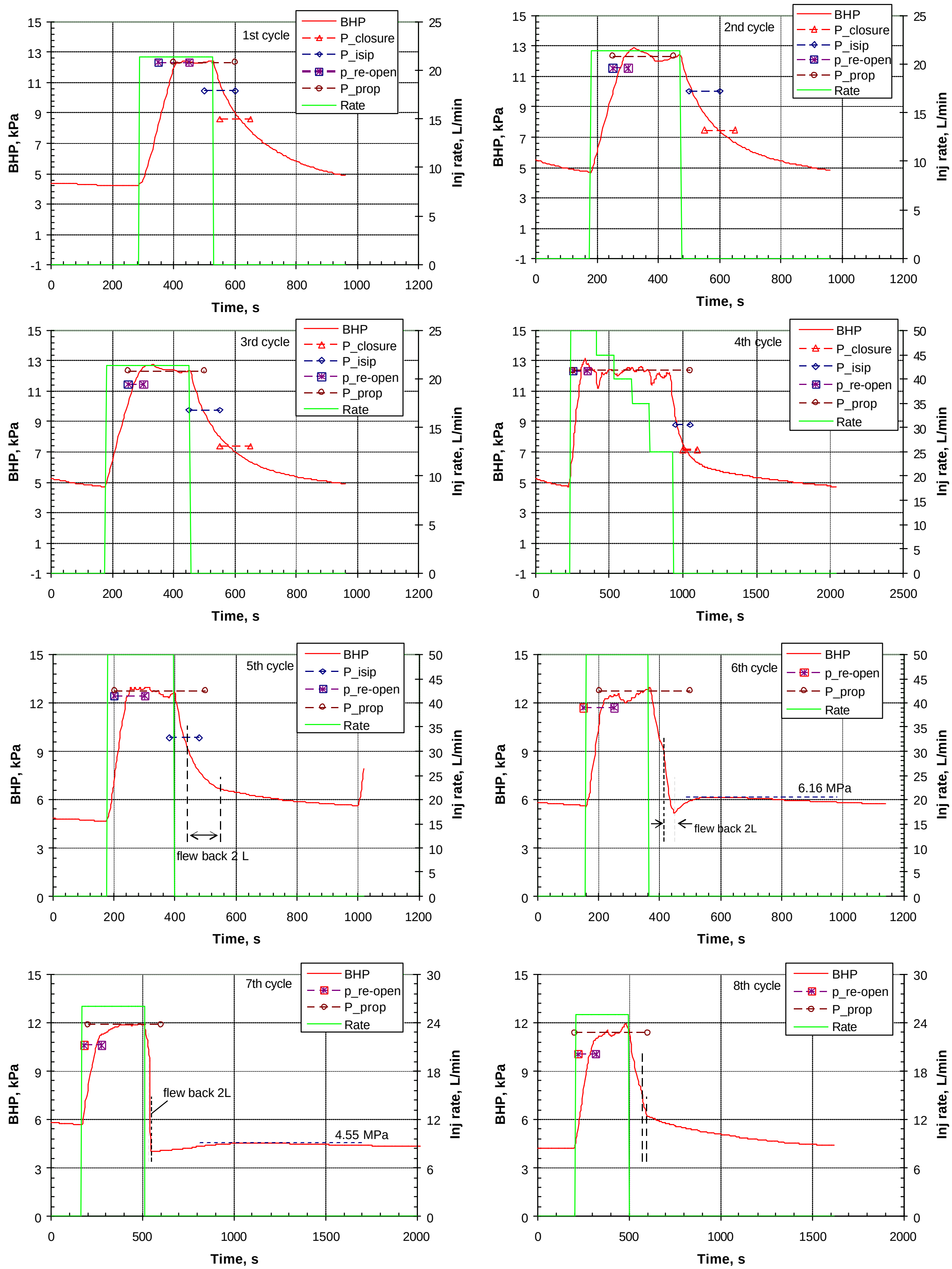


Figure A.9: Characteristic pressures determined from the various injection/shut-in cycles in testing the shaly facie (399 mTVD) at well 12-27.

FIGURES

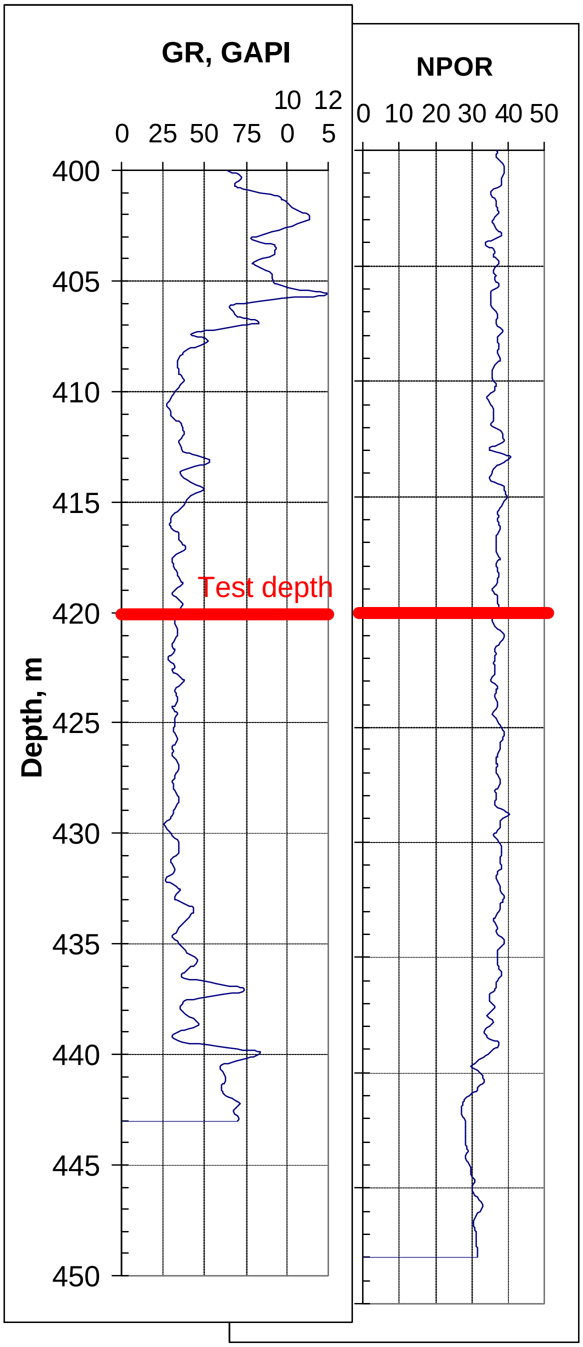


Figure 1: Test target at well 4-27 for hydraulic fracturing stress tests.

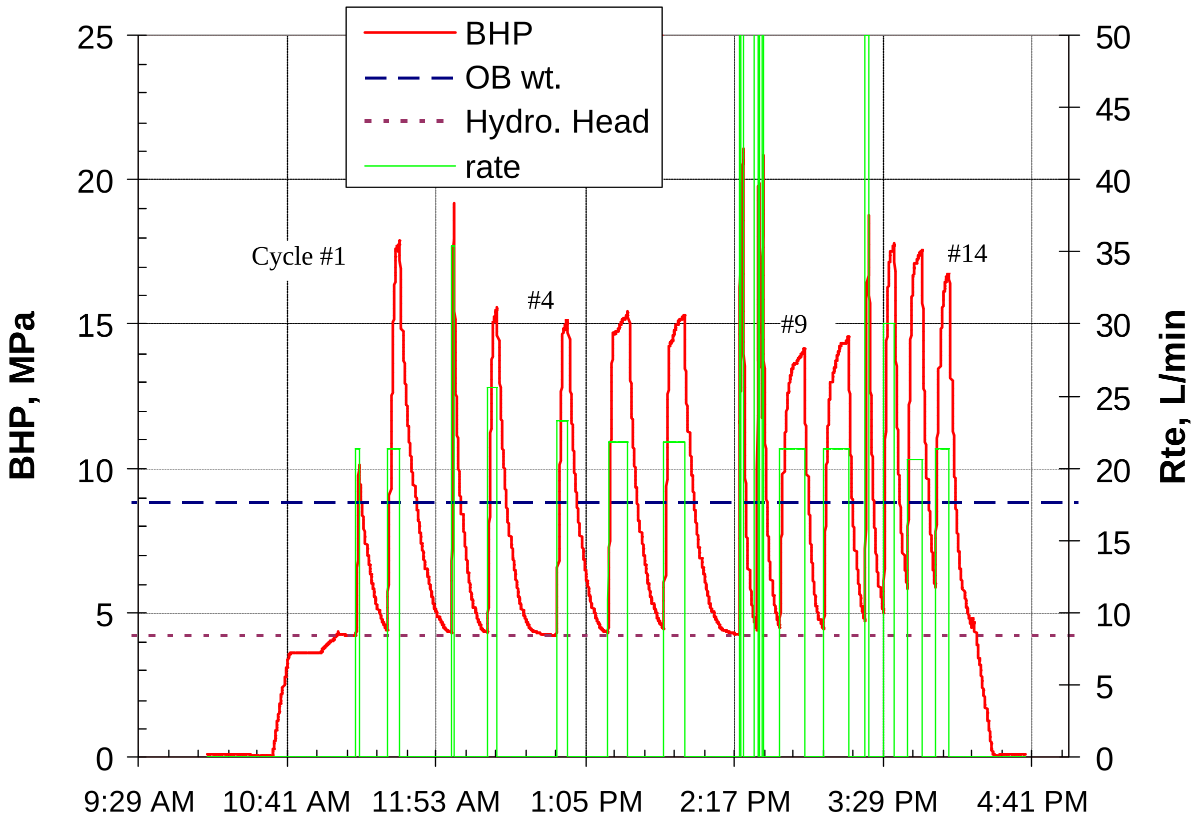


Figure 2: Recorded pressure history during the injection test in the oil sands facie at 420 mTVD at well 4-27. The bottomhole pressures ("BHP") were recorded via two downhole pressure sensors. The hydraulic head ("Hydro. head") was the water column weight. The overburden weight ("OB weight") was calculated from the density log. Similar conventions are used below unless otherwise notified.

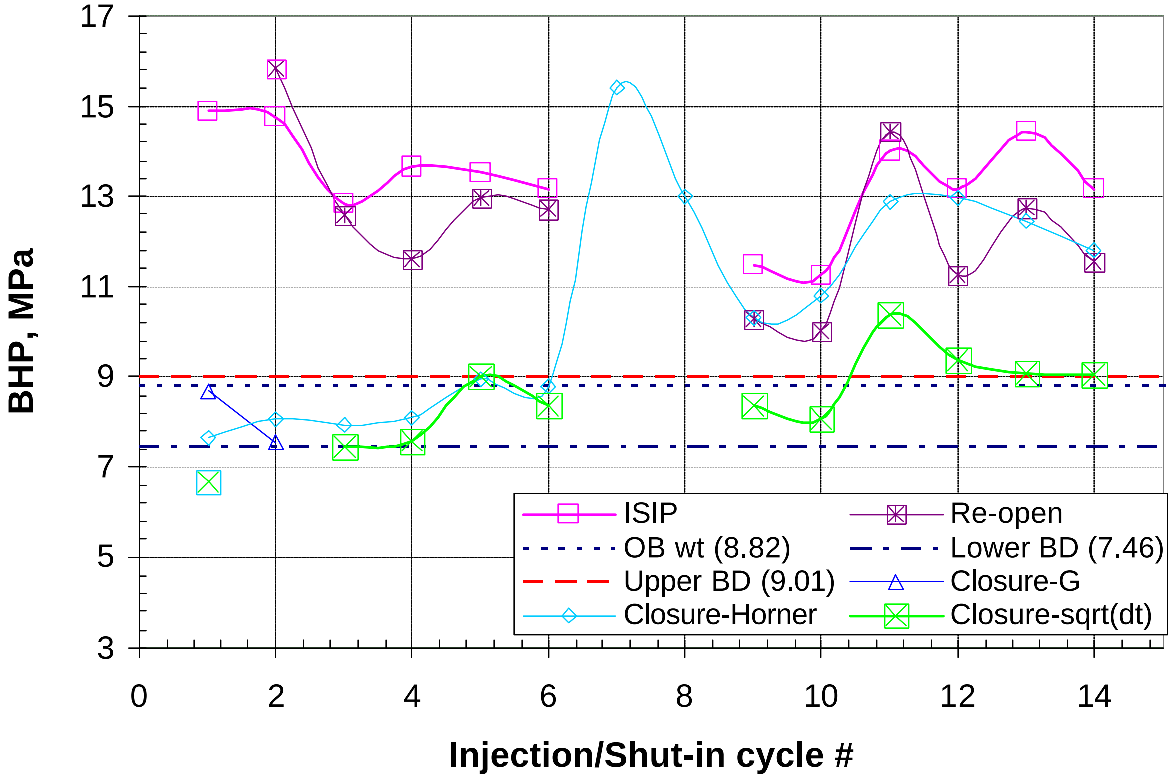


Figure 3: Various characteristic pressures interpreted from the test at 420 mTVD at well 4-27. "ISIP" denotes the instantaneous shut-in pressure, 'Re-open" the fracture re-opening pressure. "OB wt" was the overburden weight calculated from the density log. "Lower BD" and "Upper BD" specify the lower and upper bounds, respectively, for the interpreted minimum in-situ stress. "Closure-G (Horner, sqrt(dt))" is the fracture closure pressure extracted by the G-plot, Horner-plot or sqrt(dt)-plot, respectively. Relevant background information about these pressures and their interpretation techniques are discussed in Appendix A. Similar convention for the legends holds for similar plots in this report.

(a)

(b)

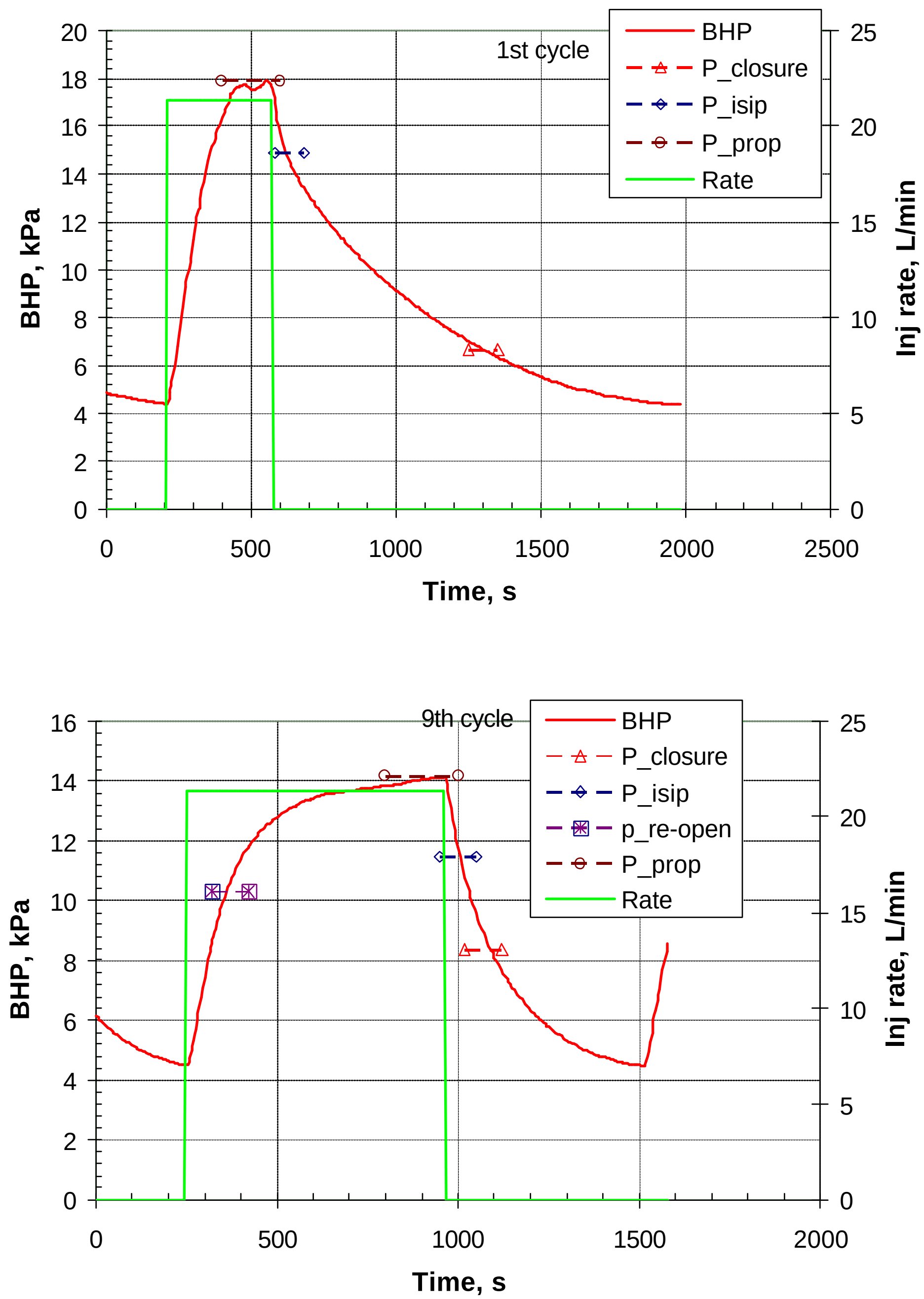


Figure 4: Comparison of pressure behaviour during injection for cycle #1 (a) and cycle #9 (b).

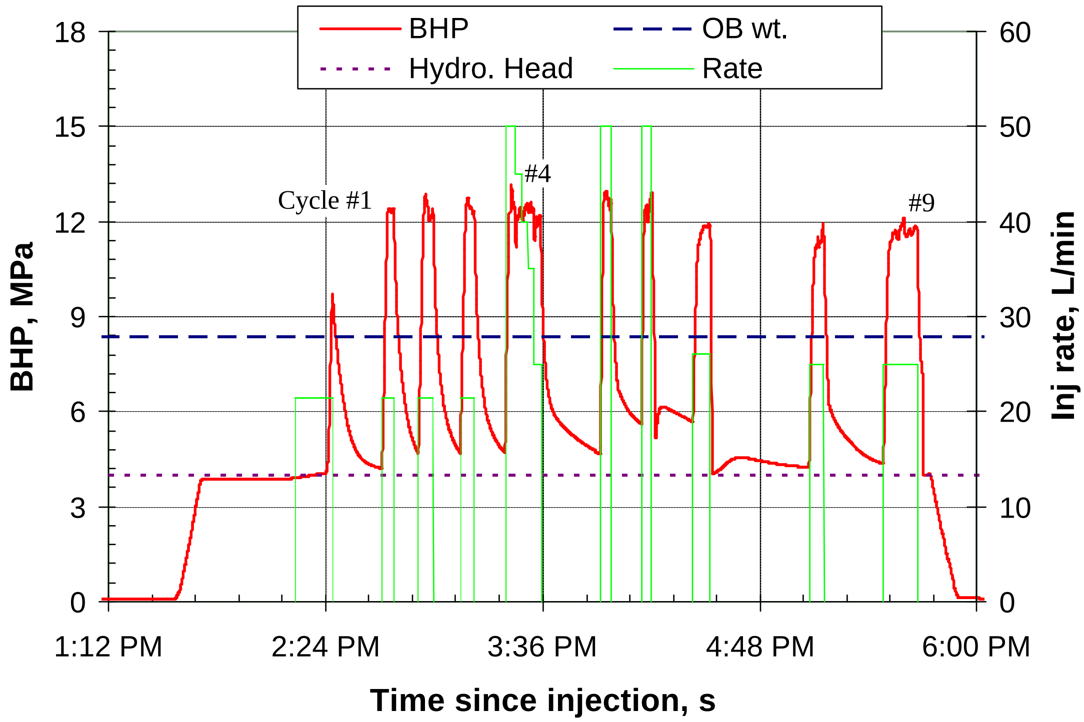


Figure 5: Recorded pressure history during the injection test in the shaly facie at 399 mTVD at well 14-27.

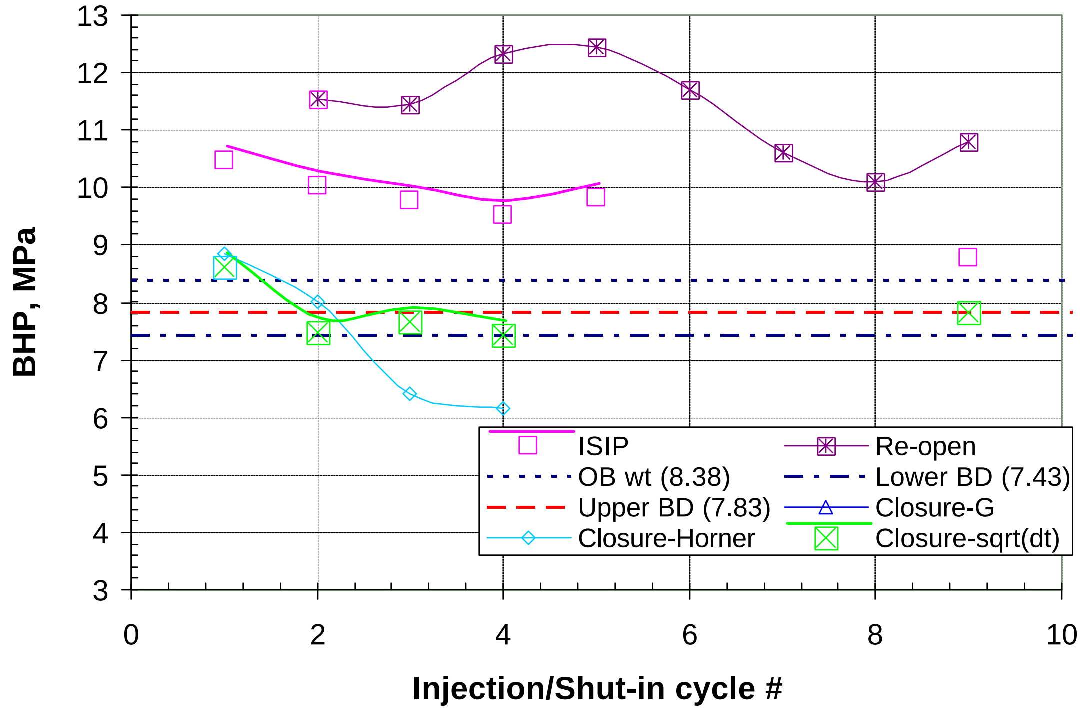


Figure 6: Various characteristic pressures interpreted from the hydraulic fracturing stress test in the shaly facie at 399 mTVD at well 12-27.

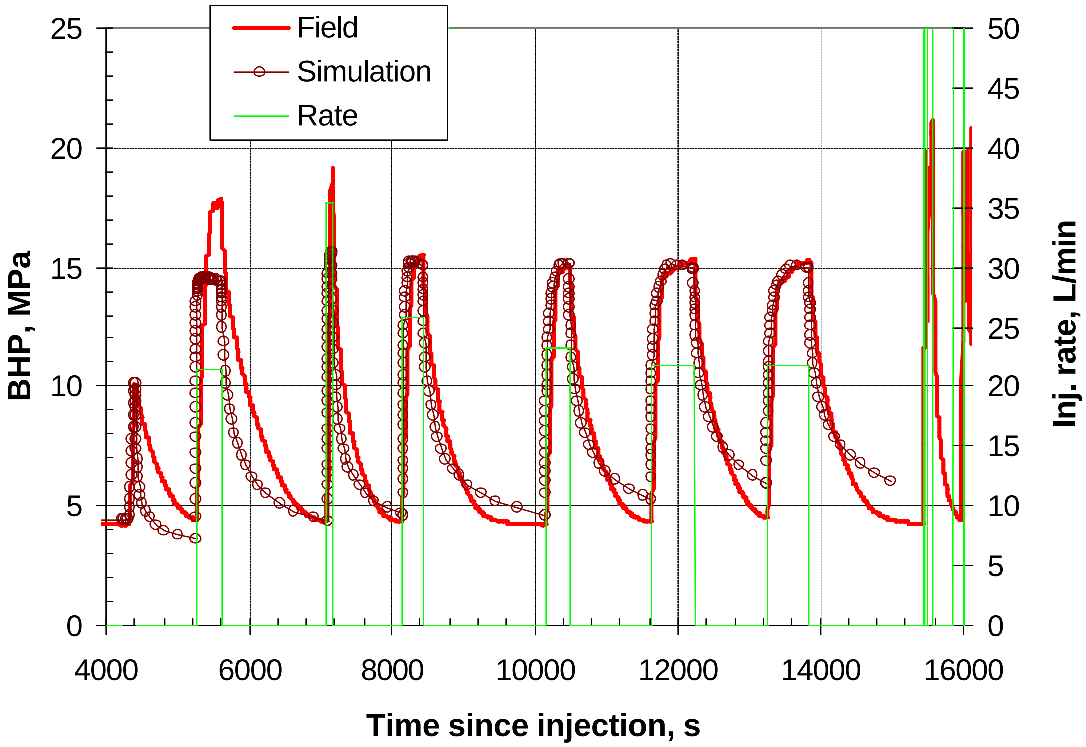


Figure 7: Comparison in the bottomhole pressure response between the simulated and field-recorded during the injection test in the oil sands facie at 420 mTVD at well 4-27.

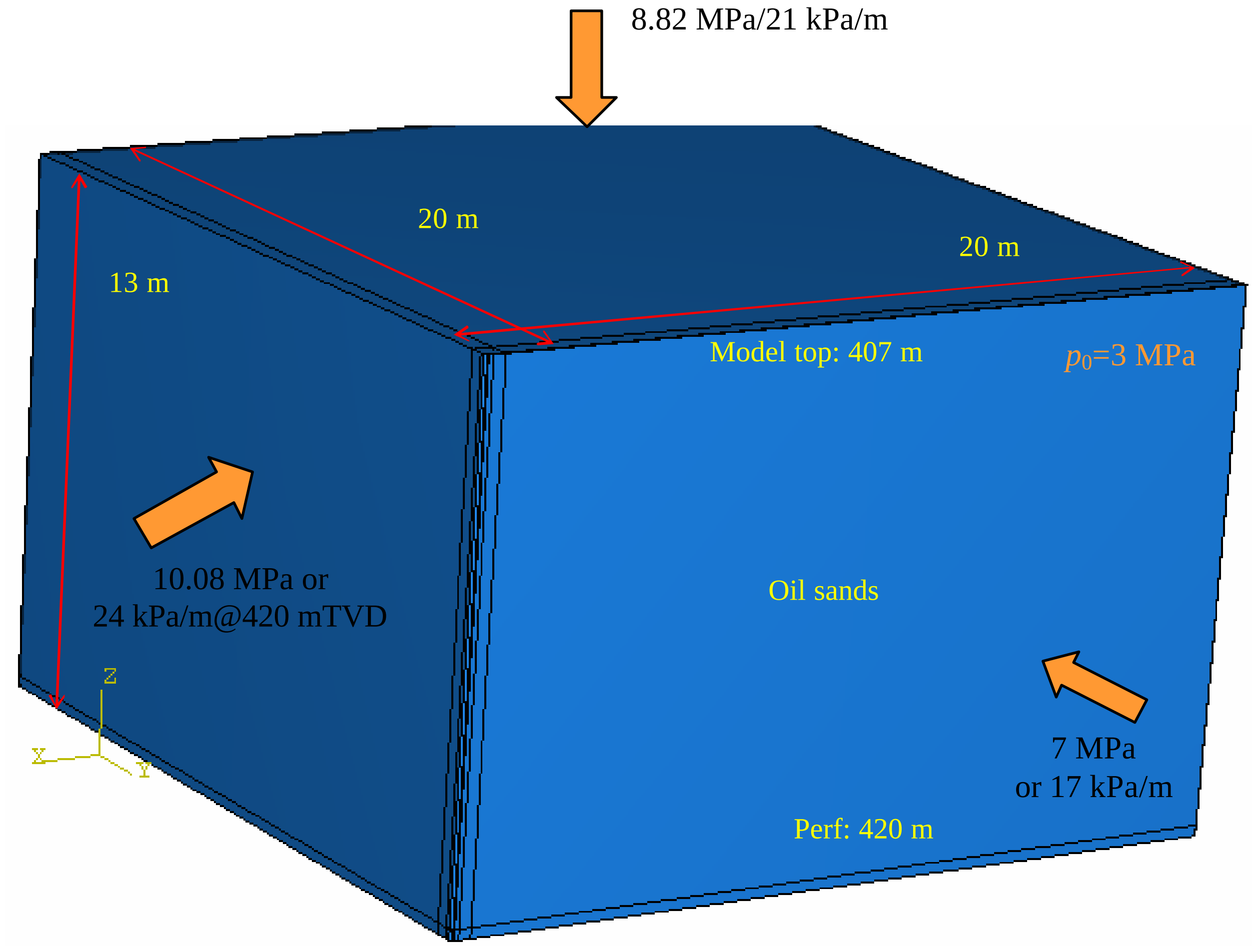


Figure 8: Geometry of the simulation model used in the history-matching shown in Figure 8. Please refer to Figure 1 for a log representation of the well. A quarter model is used because of the symmetry.

Material properties for the oil sands	
Log elastic bulk modulus (kappa)	0.007
Poisson's ratio	0.4
Drucker-Prager friction angle, deg	45
Drucker-Prager dilation angle, deg	35
Drucker-Prager cohesion, kPa	62
Initial porosity	32.5%
Initial water saturation	20%
Irreducible water saturation	15%
Initial formation permeability, md	2000
Ratio of vertical to horizontal permeability	1

Figure 9: A summary of input parameters used in history-matching the well injection test at the oil sands facie at well 4-27. The current set of parameters yielded the best match shown in Figure 8. Relevant details about each of these parameters are discussed in the text.

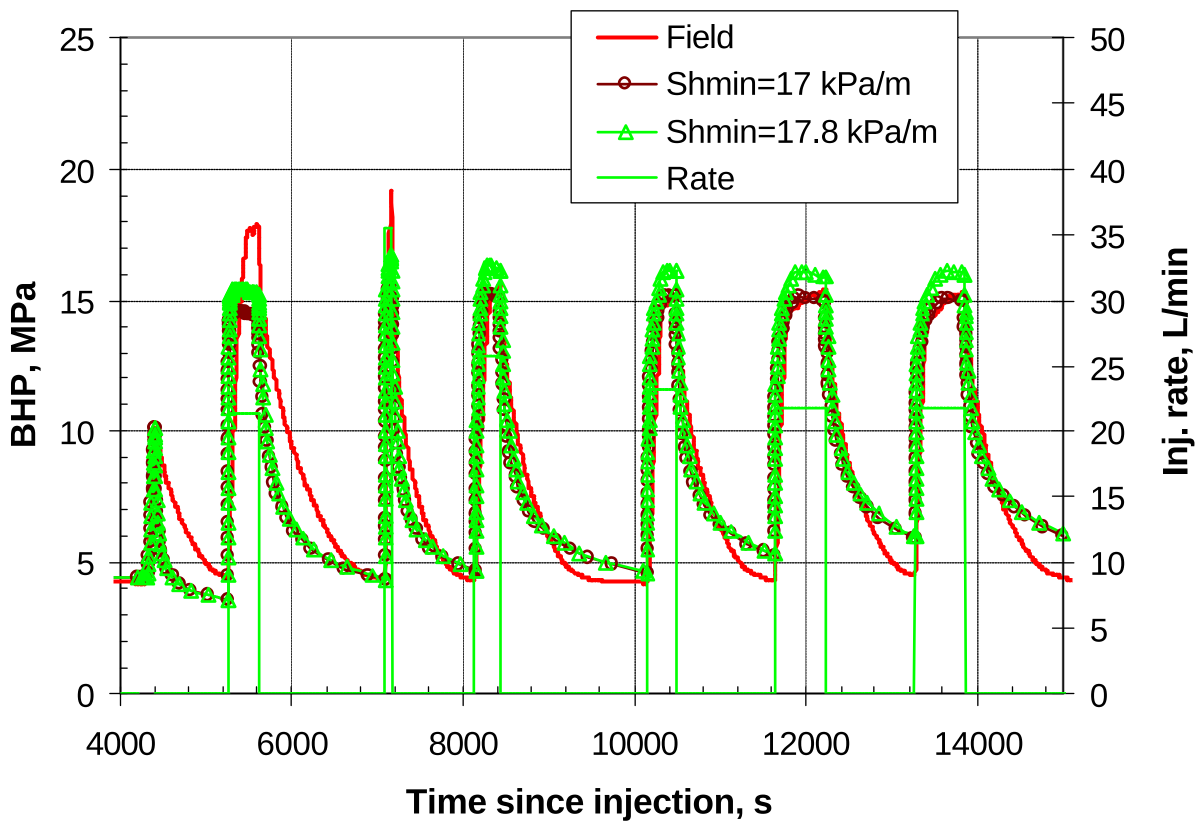


Figure 10: Effect of varying the SHmin in matching the field data.

#	Cases	Notes
1	NAOSC-sands-1	Different sizes of models. 40x40x33m, full perf. interval
2	NAOSC-sands-small1	20x20x20m, full perf. interval
3	NAOSC-sands-hlf1	20x20x20m, half perf. interval
4	NAOSC-sands-hlf-nu03	#3, but nu=0.3
5	NAOSC-sands-hlf-nu03-1	nu=0.3 but 0.45 in the perf. zone
6	NAOSC-sands-hlf-frc50	#3, fric angle=50 deg.
7	NAOSC-sands-hlf-frc45-dil35	#3, fric.=45 deg., dil.=35 deg.
8	NAOSC-sands-hlf-frc45-dil35-nu04	#7, nu=0.4
9	NAOSC-sands-hlf-frc45-dil35-rate	#8, but prescribed BHP for the 1st inj. cycle
10	NAOSC-rate-allperf	#9, different perforation extent.
11	NAOSC-rate-k05D	#9, k0=5 Darcy, Sw0=Swc=15%
12	NAOSC-rate-Sw020%	#9, Sw0=20% vs. Swc=15%
13	NAOSC-rate-skinzone	#10, but different skin zone
14	NAOSC-rate-Sw020%-nu035	#12, nu=0.35
15	NAOSC-rate-Sw020%-nu035-kvkh05	#14, kv/kh=0.5
16	NAOSC-rate-Sw020%-nu035-SHmin23	#14, Shmin=23, Shmax=29 kPa/m So, Shmin>Sv (=21 kPa/m).
17	NAOSC-rate-Sw020%-nu035-kvkh05-1	#15, but mesh refined in the frac layer
18	NAOSC-rate-Sw020%-nu035-kvkh05-2	#15, further refined mesh vertically
19	NAOSC-rate-Sw020%-nu035-kvkh05-3	#18, new meshing technique
20	NAOSC-rate-Sw020%-nu035-kvkh05-4	#19, reduced integration elements Did not converge. The mesh distorted.
21	NAOSC-rate-Sw020%-nu035-3	#18, but with kv/kh=1
22	NAOSC-rate-Sw020%-nu04-3	#21, but nu=0.4
23	NAOSC-rate-Sw020%-nu04-3	#22 re-computed with added 3 more cycles
24	NAOSC-rate-Sw020%-nu04-3-strs	#23, but Shmin=16.67, Shmax=24, Sv=21. Previously, Shmax=26, Shmin=17.76

Figure 11: List of sensitivity cases run in history-matching the injection test at the oil sands facie at well 4-27.

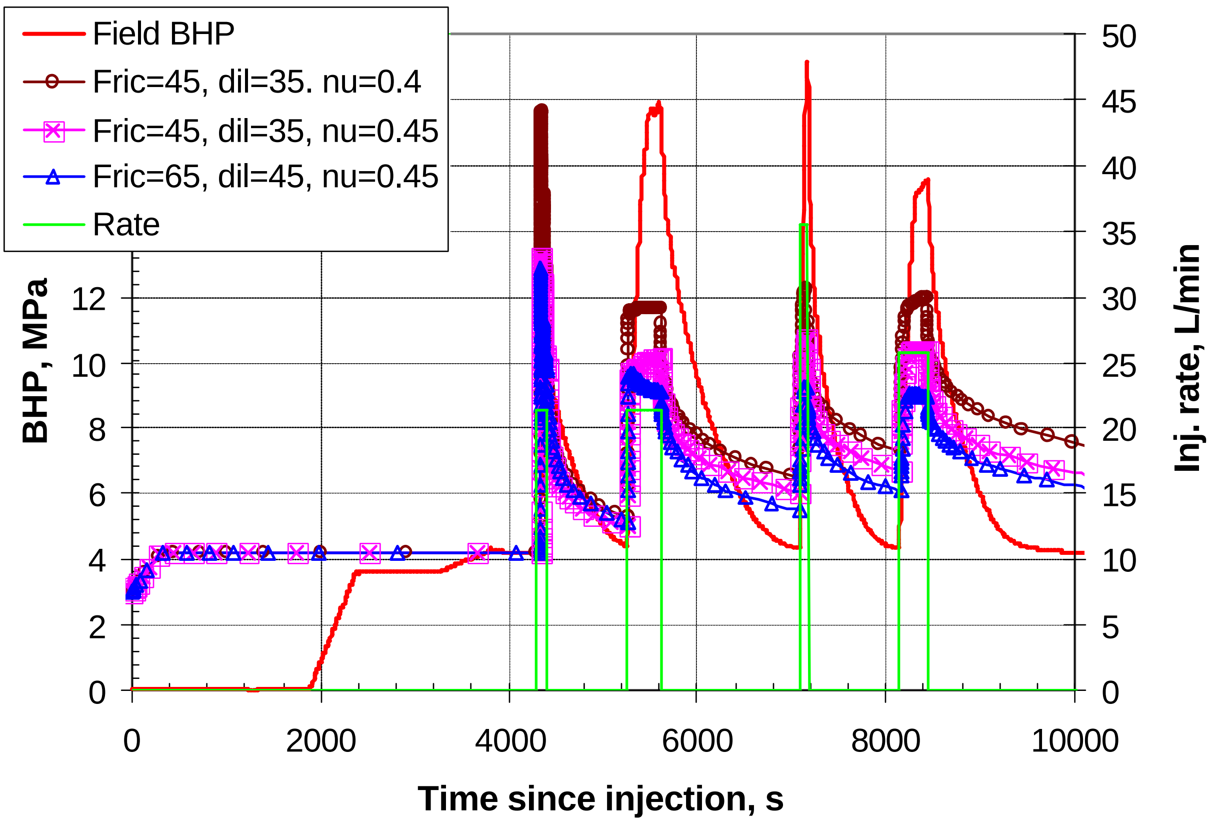


Figure 12: Effect of varying Poisson's ratio, friction and dilation angles in matching the field data.

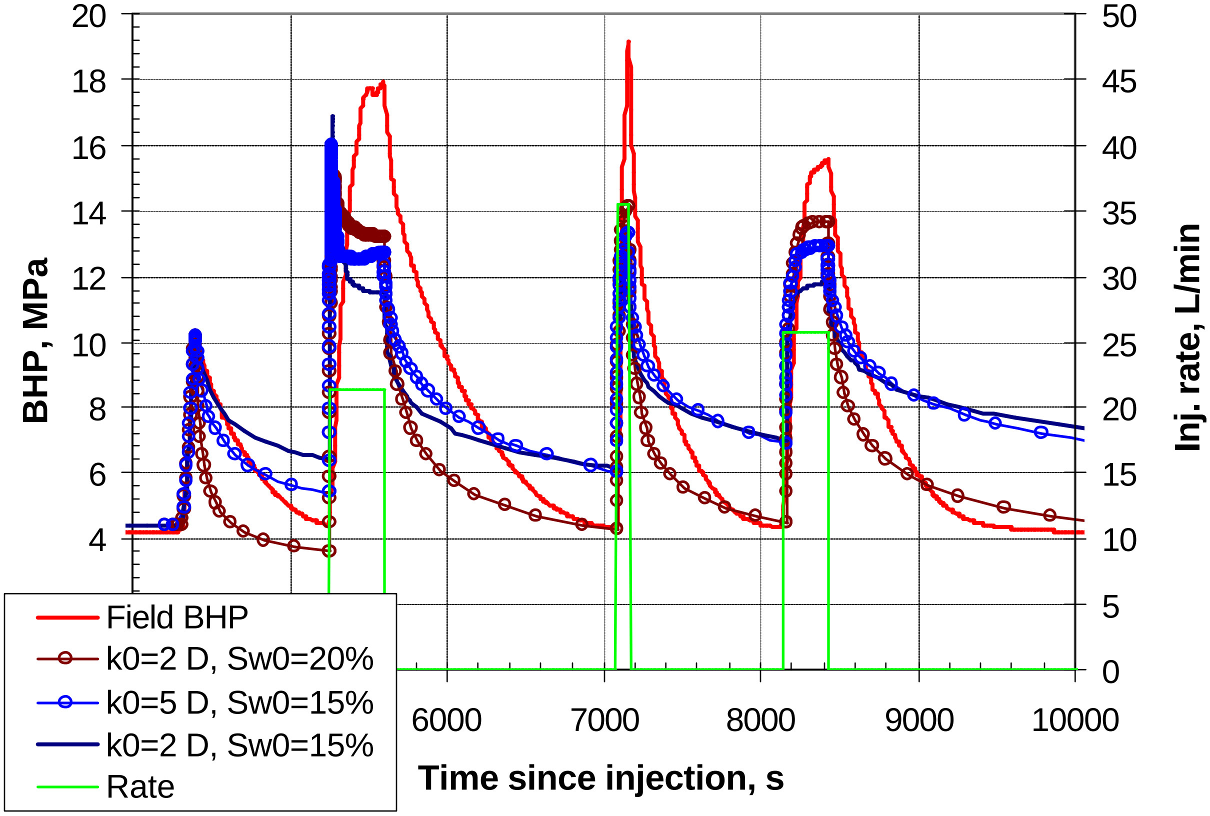


Figure 13: Effect of formation permeability (k0) and initial water saturation (Sw0) on the history-matching.

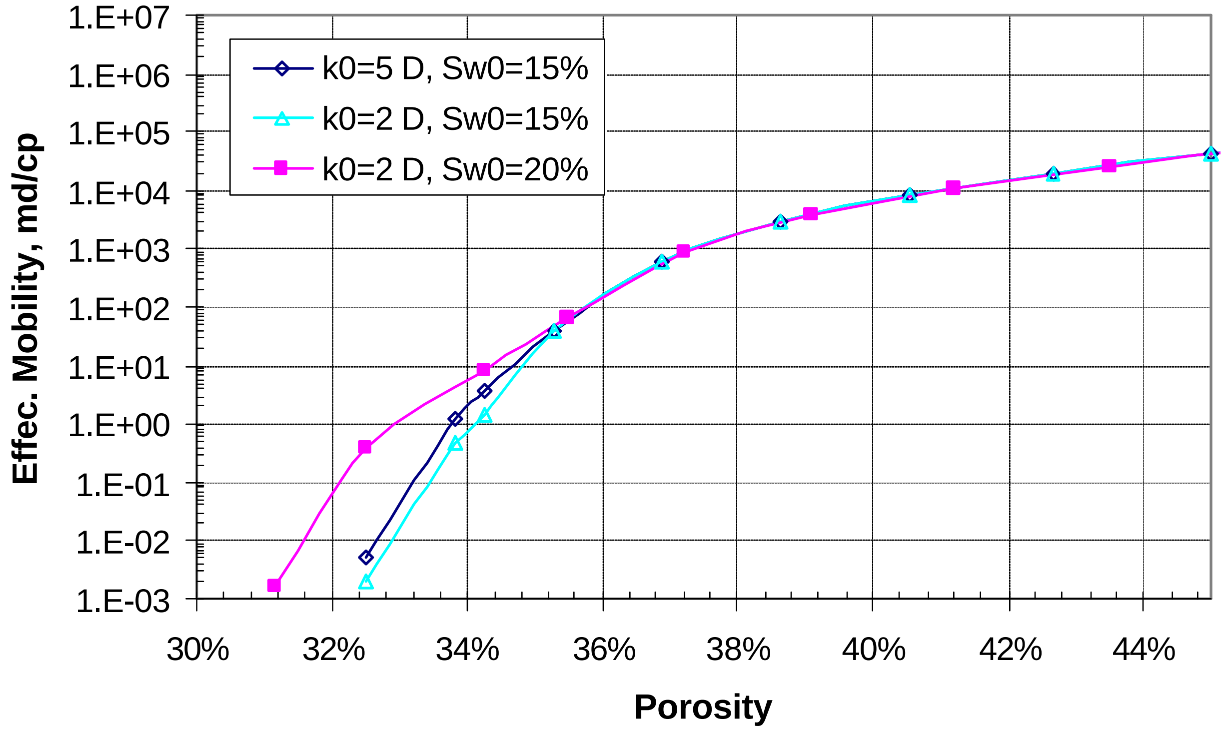


Figure 14: Effective water mobility vs. porosity.

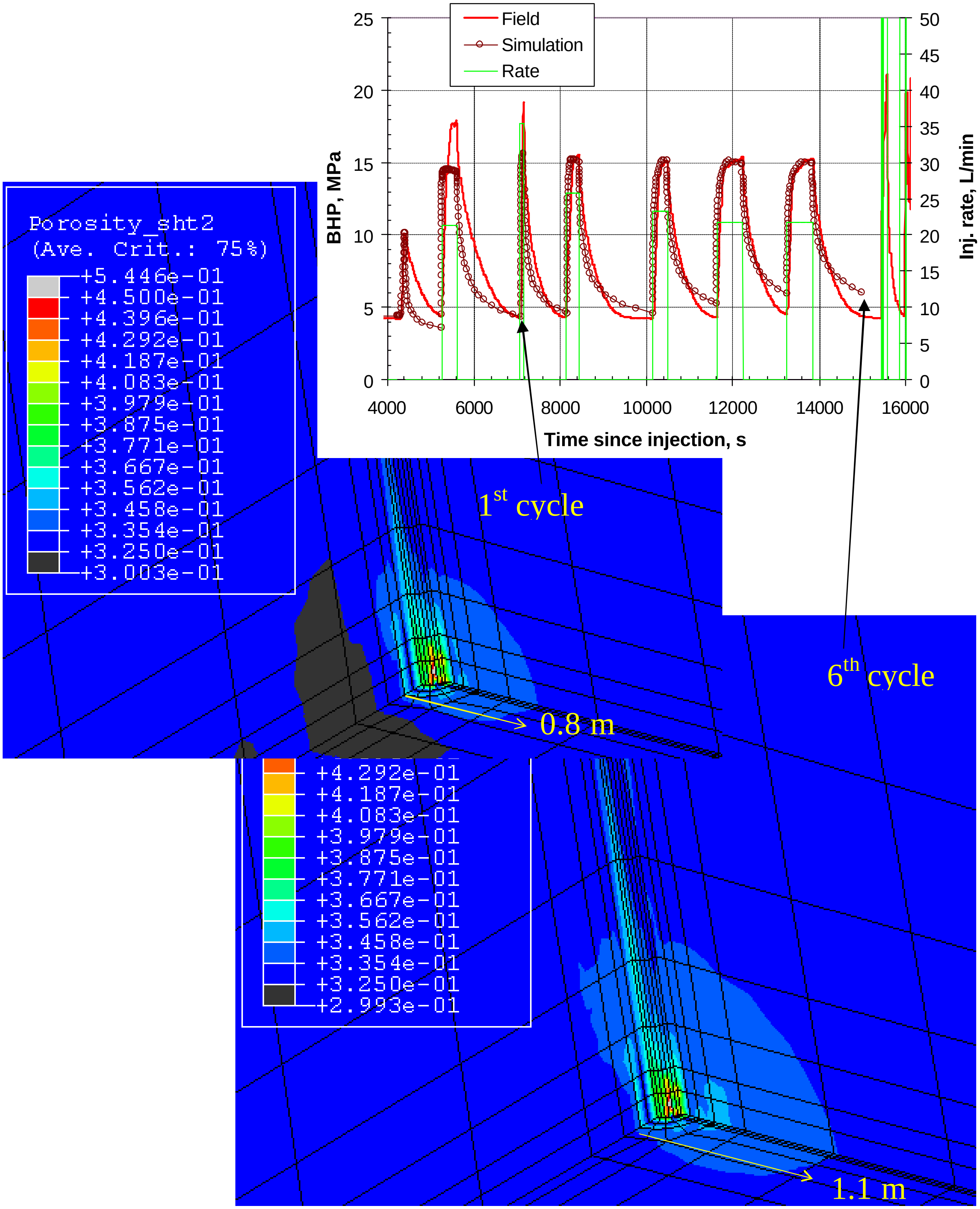


Figure 15: Extent of fracture propagation as marked by the high-porosity zone. The contour plots denote the porosity.

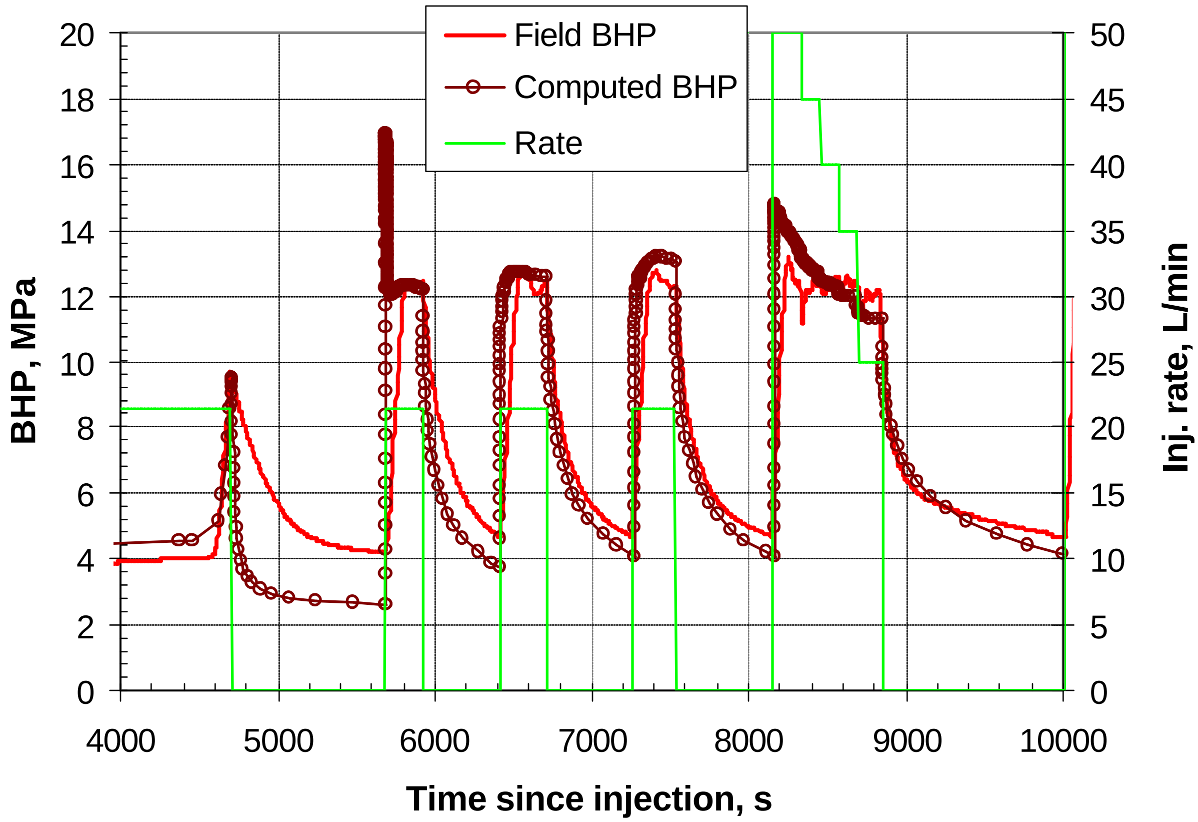
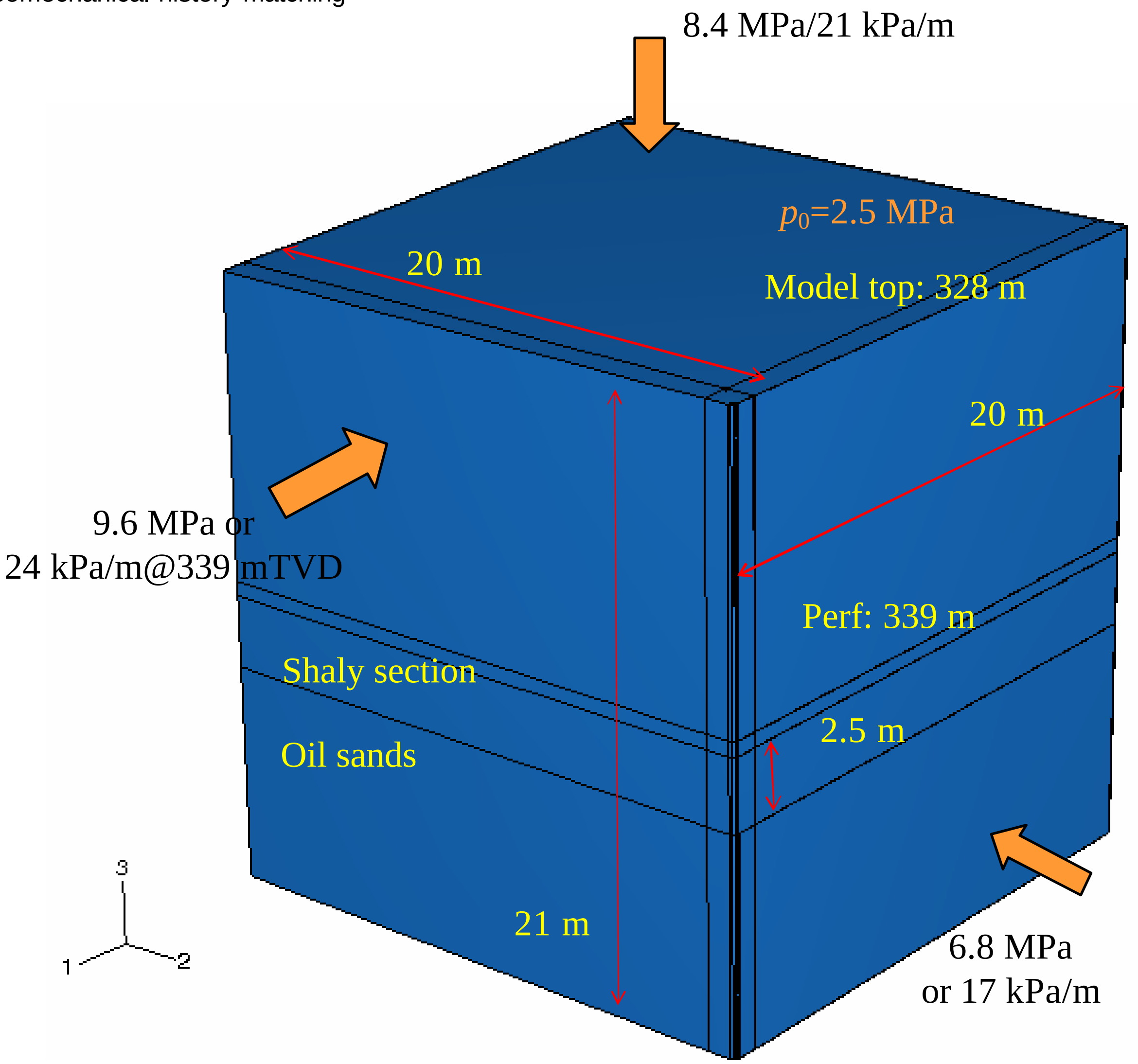


Figure 16: Comparison in the bottomhole pressure response between the simulated and field-recorded during the injection test in the shaly facie at 399 mTVD at well 12-27.



Material properties for the oil sands	
Log elastic bulk modulus (kappa)	0.007
Poisson's ratio	0.4
Drucker-Prager friction angle, deg	45
Drucker-Prager dilation angle, deg	35
Drucker-Prager cohesion, kPa	62
Initial porosity	32.5%
Initial water saturation	20%
Irreducible water saturation	15%
Initial formation permeability, md	2000
Ratio of vertical to horizontal permeability	1

Material properties for the shaly section	
Log elastic bulk modulus (kappa)	0.001
Poisson's ratio	0.35
Drucker-Prager friction angle, deg	45
Drucker-Prager dilation angle, deg	25
Drucker-Prager cohesion, kPa	62
Initial porosity	25%
Initial water saturation	100%
Irreducible water saturation	N/A
Initial formation permeability, md	1
Ratio of vertical to horizontal permeability	1

Figure 17: Computational model, in-situ stress and material properties used in matching the shaly facie at well 12-27 and giving the good fit shown in Figure 17.

APPENDIX II.

GEOMECHANICAL TESTS, MCMURRAY FORMATION
PARAMOUNT LEISMER 09-28-78-10W4M, ALBERTA

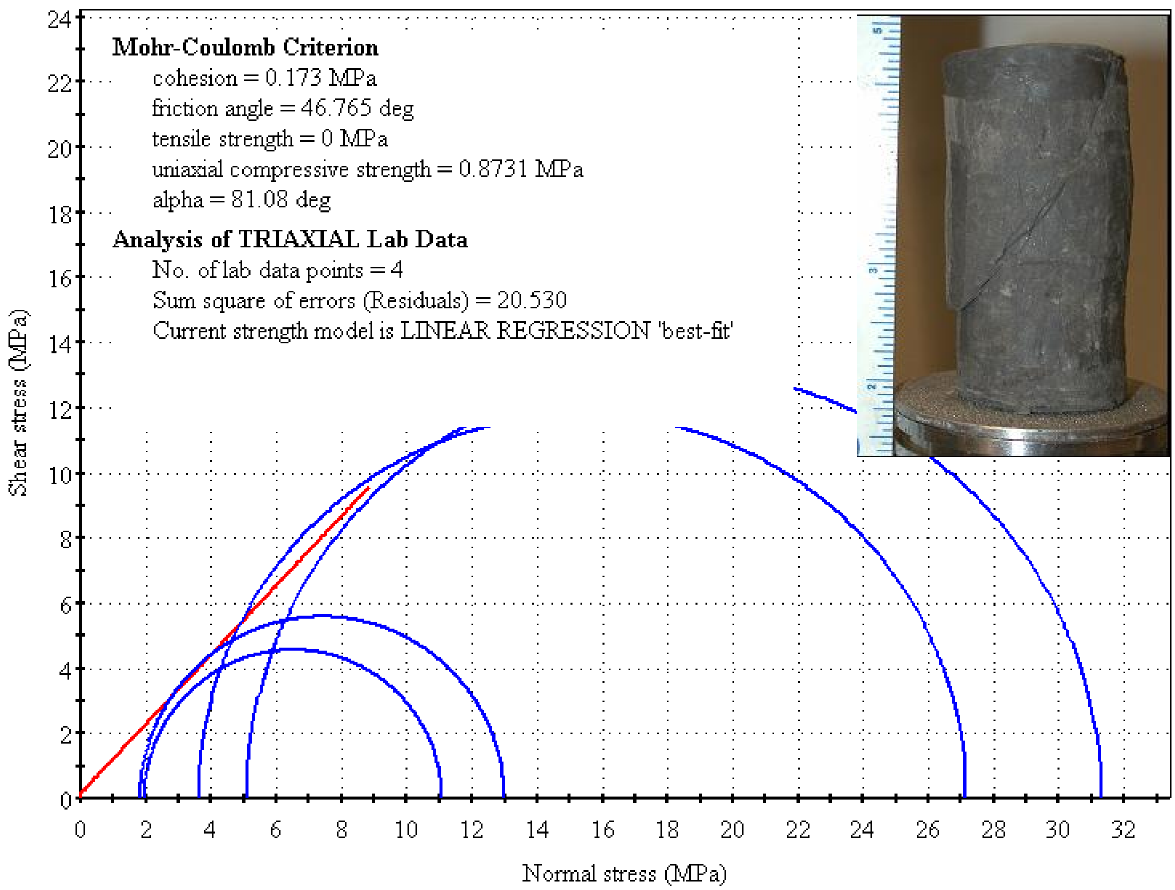
PREPARED BY ADVANCED GEOTECHNOLOGY

North American Oil Sands Corporation
Calgary, Alberta

GEOMECHANICAL TESTS, MCMURRAY FORMATION, PARAMOUNT LEISMER 09-28-78-10W4M, ALBERTA

NORTH AMERICAN OIL SANDS CORPORATION

November, 2005 ***AGI FILE: 10-247***



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GEOMECHANICAL TESTS,
McMURRAY FORMATION,
PARAMOUNT LEISMER 09-28-78-10W4M,
ALBERTA

NORTH AMERICAN OIL SANDS CORPORATION

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PERMIT TO PRACTICE
ADVANCED GEOTECHNOLOGY INC.

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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

ADVANCED GEOTECHNOLOGY

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EXECUTIVE SUMMARY

This report presents the results of a scoping geomechanical testing program conducted on preserved McMurray Formation mudstone and oil sands cores from Paramount Leismer 09-28-78-10W4M, north-eastern Alberta. Advanced Geotechnology Inc. (AGI) personnel selected the mudstone and oil sands cores for preservation at Core Laboratories in Calgary. To ensure high quality samples were obtained at saturations close to their in-situ condition, the mudstone cores were preserved unfrozen using a wax immersion method and the oil sand cores were preserved in a frozen state. Laboratory undrained and drained triaxial compression tests were conducted on 6 mudstone and 5 oil sands core plugs, respectively, by the Petroleum Geomechanics Group in Civil Engineering Department at the University of Alberta.

The critical mudstone and oil sand strength properties, i.e., peak and residual cohesion and friction angle, and their deformation, volume change and permeability behaviour were determined in triaxial compression tests over a range of confining stresses representative of SAGD reservoir conditions. The results of this testing program are compared to the original assumptions used in an earlier geomechanical-reservoir simulation study conducted for NAOSC. These laboratory results have application to geomechanical reservoir modeling of SAGD processes and sets the groundwork for a future geomechanical testing program at elevated temperatures.

Recommendations are provided for improving the quality and value of the data obtained in future laboratory programs like this one. A second phase of testing at SAGD relevant temperatures and pressures is recommended.

SUMMARY AND CONCLUSIONS

Core Preservation and Sampling

1. A total of 12 frozen oil sands and 6 unfrozen mudstone core samples from McMurray Formation were selected from Paramount Leismer 09-28-78-10W4M for preservation. The oil sands samples were frozen and the mudstone samples were preserved unfrozen in wax. All of the preserved core samples were sent to the University of Alberta (U of A) for a geomechanical testing program.

2. Twelve core samples of shale and interbedded shale and oil sands from Paramount Leismer 03-03-79-10W4M were also preserved unfrozen in wax and sent to U of A for possible future testing, but these cores were not tested in this program.

Rock Mechanical Property Testing

Mudstones

1. Six vertical core plugs were obtained by U of A from the wax-preserved unfrozen full diameter mudstone cores.

2. The mudstones were non-fissile and mostly contained silt sized particles with about 4% to 22% clay sized fractions (<4µm). The average natural water content, water saturation and porosity of the mudstone samples were 9.6%, 91.2% and 20.4%, respectively.

3. Isotropically consolidated undrained triaxial compression tests (CIU) with pore pressure measurement were conducted on all of the mudstone core samples at confining stresses of 2.57 to 8.35 MPa and a pore pressure of 2.0 MPa. In each of the triaxial test, steady state core flow permeability was measured at the residual strength.

4. Mohr-Coulomb and Hoek-Brown failure criteria were fit to the laboratory peak and residual strength data. The peak cohesion and peak friction angle of the mudstone samples obtained from the Mohr-Coulomb analyses were 0.17 MPa and 47°. The residual cohesion and residual friction angle were 0.0 MPa and 39°. A residual friction angle of 39° indicates the existence of a substantial post-peak frictional resistance to shear deformation in the mudstone samples.

5. Non-linear Hoek-Brown failure criteria did not provide a better fit than a linear Mohr-Coulomb criteria for both peak and residual mudstone strength data. The peak and residual strength data were fit with unconfined compressive strengths (UCS) of 2.11 and

0.73 MPa, respectively. For peak and residual strength fits the m and s parameters were 12.6 and 6.9, respectively.

6. During the undrained triaxial compression tests, all of the mudstone samples showed brittle behaviour with a post-peak residual strength. All but two of the samples tested at confining stresses of 6.53 and 8.35 MPa, show a very small pre-peak increase in pore pressure followed by large post-peak pore pressure reduction. Tests ST4 and ST5 show strong pre-peak pore pressure increases followed by a post-peak pore pressure reduction. The differences in pre- and post-peak pore pressure responses are function of magnitude of applied confining stress.

7. The initial static Young's moduli for the mudstones ranged from 0.27 GPa to 2.11 GPa. Since the triaxial tests were conducted at undrained conditions, the net volume change is zero and hence Poisson's ratios were not calculated.

8. Steady-state core flow permeabilities measured at residual strength at axial strain levels of 5.3% to 12.5% range from 5.47 μD to 0.26 μD, respectively. The permeability of mudstone samples decrease with increasing the magnitude of strain at the residual strength.

Oil Sands

1. Five vertical core plugs were obtained by U of A from the frozen full diameter oil sands core samples.

2. The grain size distributions in these oil sands samples were poorly graded with most of the grains falling in the range of very fine to fine sand. On average, the samples contained 15.5% bitumen, 2.0% water and 82.6% sand by total weight. The average porosity was 31.7%, with 89% of the pore volume occupied by bitumen and 11% by water.

3. Isotropically consolidated drained triaxial compression tests (CID) were conducted on all of the oil sands core samples at effective confining stresses of 0.47 to 8.07 MPa with a pore pressure of about 1 MPa. In each triaxial test, steady state core flow permeabilities were measured before shearing, at or near to the peak strength, and at the post-peak residual strength.

4. Bitumen was extracted from all of the oil sands samples prior to the triaxial testing, except for sample NTX2. Triaxial tests NTX1 and NTX2 were conducted on identical core plugs but, NTX1 was tested without bitumen and NTX2 was tested with bitumen in place.

5. Mohr-Coulomb and Hoek-Brown failure criteria were used to fit the laboratory peak and residual strength data. The peak cohesion and peak friction angle of the oil sands samples obtained from the Mohr-Coulomb analyses were 0.7 MPa and 32°. The residual cohesion and residual friction angle were 0.4 MPa and 32°. The identical peak and residual friction angles in these tests suggest some degree of initial sample disturbance.

6. The peak and residual strength data were fit with unconfined compressive strengths (UCS) of 0.53 and 0.66 MPa, respectively using non-linear Hoek-Brown failure criteria. For both of these peak and residual strength fits the m and s parameters were about 6.5.

7. During the triaxial compression tests, all of the oil sands samples show a strong post-peak dilative behaviour with high dilation angles that depend on the effective confining stress. The range of pre- and post-peak dilation angles were -5.7° to -54.1° and 6.9° to 27.4°, respectively. A negative dilation angle corresponds to a volume decrease, according to the convention used in this report. All samples except for samples NTX4 and NTX5 show pre-peak volumetric contraction followed by post-peak volumetric dilation. Samples NTX4 and NTX5 which were tested at higher effective confining stresses exhibited strong volumetric contraction through out the shearing.

8. The initial static Young's moduli for oil sands ranged from 0.24 GPa to 1.19 GPa. The initial static Poisson's ratios ranged between 0.25 and 0.32.

9. The steady-state water core permeabilities measured at various pre- and post-peak strain levels range from 0.0307 mD to 261 mD. The lowest permeability was measured on sample NTX2 which was tested without bitumen extraction. The results show that the permeability actually decreased with shearing for both volumetric contraction and dilation. The higher the axial strain and the closer the sample was to the residual condition, the lower the permeability. The permeability reduction due to shear-induced volume change is attributed to the formation of a lower permeability zone along the shear planes due to grain crushing and particle re-arrangement.

RECOMMENDATIONS

1. This scoping laboratory testing program was conducted to obtain basic geomechanical properties of McMurray Formation oil sands and mudstones. A future laboratory test program should be conducted at elevated temperatures, more representative of the SAGD process proposed for the setting. **(High Priority)**

2. For new laboratory tests, an injection stress path should be followed, where possible. **(High Priority)**

3. In a future testing program, some consideration should be given to conducting ultrasonic compressional and shear wave velocity tests on mudstone and oil sands samples to obtain dynamic elastic properties, which can be correlated to static laboratory tests. **(Medium Priority)**

4. Laboratory geomechanical data should always be used in conjunction with log data and core recovery data to develop a geomechanical property profile for simulation purposes, especially in weak mudstone intervals. **(Medium Priority)**

1. INTRODUCTION

1.1 Objectives

The overall objective of this investigation was to design and manage a laboratory testing program to determine geomechanical and permeability properties of selected McMurray Formation oil sands and the interbedded mudstones from Paramount Leismer 09-28-78-10W4, Leismer area, Alberta. A separate report was previously prepared by Advanced Geotechnology Inc. (AGI) on coupled reservoir-geomechanical simulation during SAGD in the same geological setting (AGI, 2004).

1.2 Scope of Work

1. Development of the project scope and detailed plan, including meetings with North American Oil Sands Corporation (NAOSC) personnel, visits to the AEUB Core Storage facility and Core Laboratories (Calgary) for core inspection and sampling, and visits to the University of Alberta (U of A) to discuss the testing plan and inspect their facility.

2. Design, manage and interpret the results of laboratory testing program on initially frozen oil sands and unfrozen mudstone cores of the McMurray Formation.

3. Monitor the progress of the testing program, making modifications as required.

4. Provide an analysis and interpretation of the laboratory test results.

5. Prepare 3 copies of the final report.

1.3 Authorization

This investigation was authorized by Mr. Glenn Fung of NAOSC. A contract between the University of Alberta and NAOSC, signed in May 2005, describes the terms and conditions pertaining to the laboratory testing program. (U of A Reference No. SFR2243, Purchase Order No. CS00000138)

2. GEOLOGICAL SETTING

The location of the cored well, Paramount Leismer 09-28-78-10W4M, is shown in Figure 2.1. The McMurray Formation oil sands and the interbedded mudstones of primary interest for this study are at approximately 400 metres depth. The sediments overlying the reservoir include, from surface, Quaternary-aged sediments consisting mainly of glacial till beneath muskeg, shale-dominated Colorado Group strata, the predominantly sand-rich Grand Rapids Formation, and the shales of the Clearwater Formation. Underlying the Clearwater Formation are the interbedded sandstones and mudstone of the Wabiskaw Formation. This relatively thin unit overlies the upper, fine-grained portion of the McMurray Formation, which is typically not of reservoir quality. The base of the non-reservoir portion of the McMurray Formation in the area is marked by a thin mudstone unit termed the McMurray ‘A’ marker, distinguished by a strong gamma ray response.

The geology of the McMurray Formation bitumen reservoir is relatively consistent through the area. The reservoir generally consists of a top water or gas “transition” zone approximately 5 metres thick, a gross bitumen zone 30 to 40 metres thick, and a bottom water “transition” zone roughly 5 metres thick. Below this bottom water zone are the carbonates of the Beaverhill Lake Group. Discontinuous mudstone “plugs” or “breccias” may occur within the sand-dominated bitumen pay zone. As observed in core, these are considered to be of insufficient lateral extent to interfere with reservoir continuity (AGI, 2004). Thin centimetre-scale coal layers may also be present, but these are also laterally discontinuous.

In some wells in the area, the reservoir zone occurs immediately below the McMurray ‘A’ marker, but in other wells within the 4 section project area, the McMurray ‘A’ marker is underlain by up to 15 metres of bioturbated interbedded sandstone and mudstone, beneath which the bitumen pay zone is encountered. A notable feature of the bitumen pay zone observed in some cores is the high foreset dip of the sand layers, measured at 45° to 50° over some intervals, but closer to 20° in most zones. A gamma ray log of the reservoir section from the 9-28 well is presented in Figure 2.2

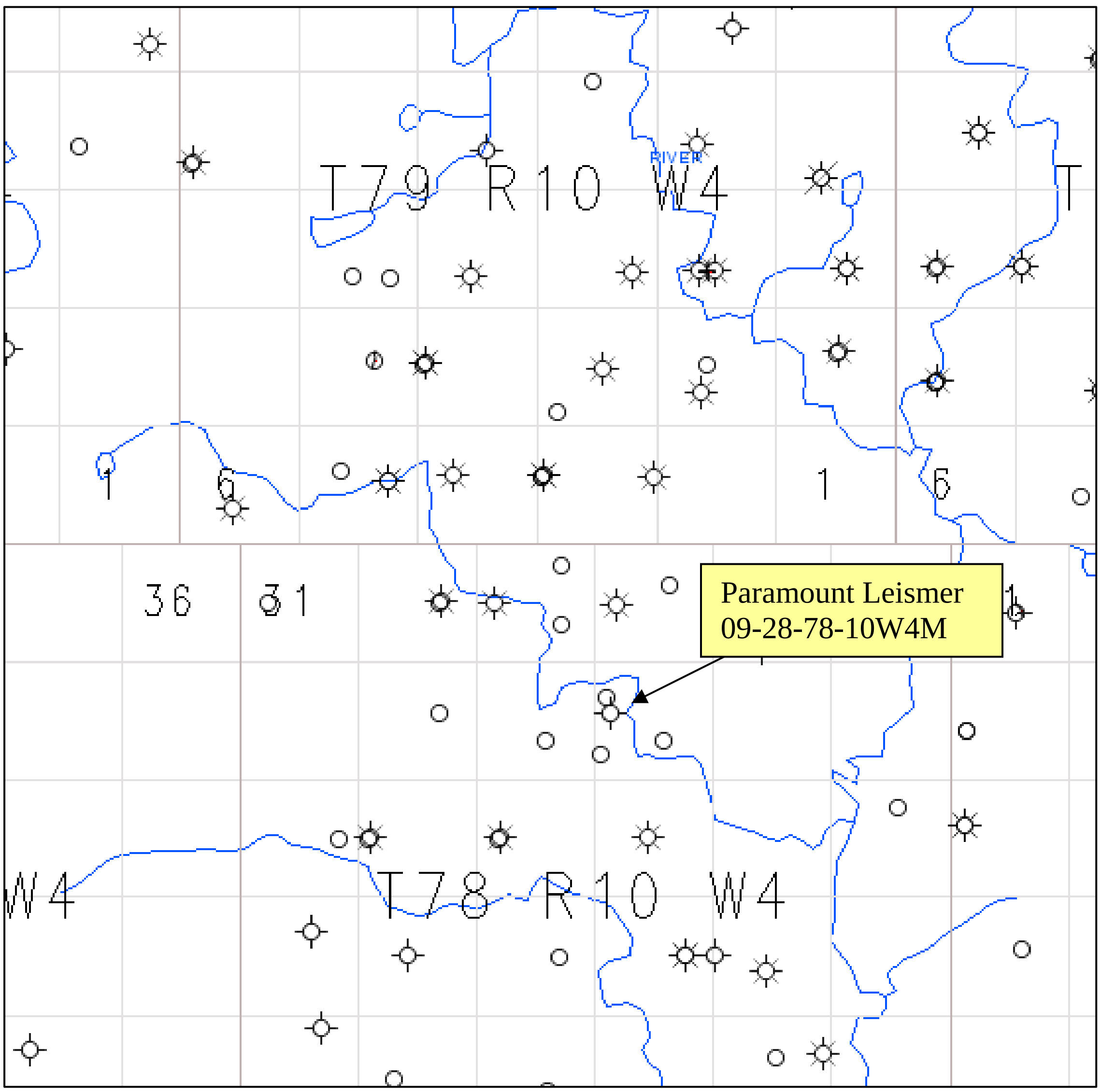

Figure 2.1: Location map showing the Paramount well 09-28-78-10W4M in the Leismer field, Alberta.

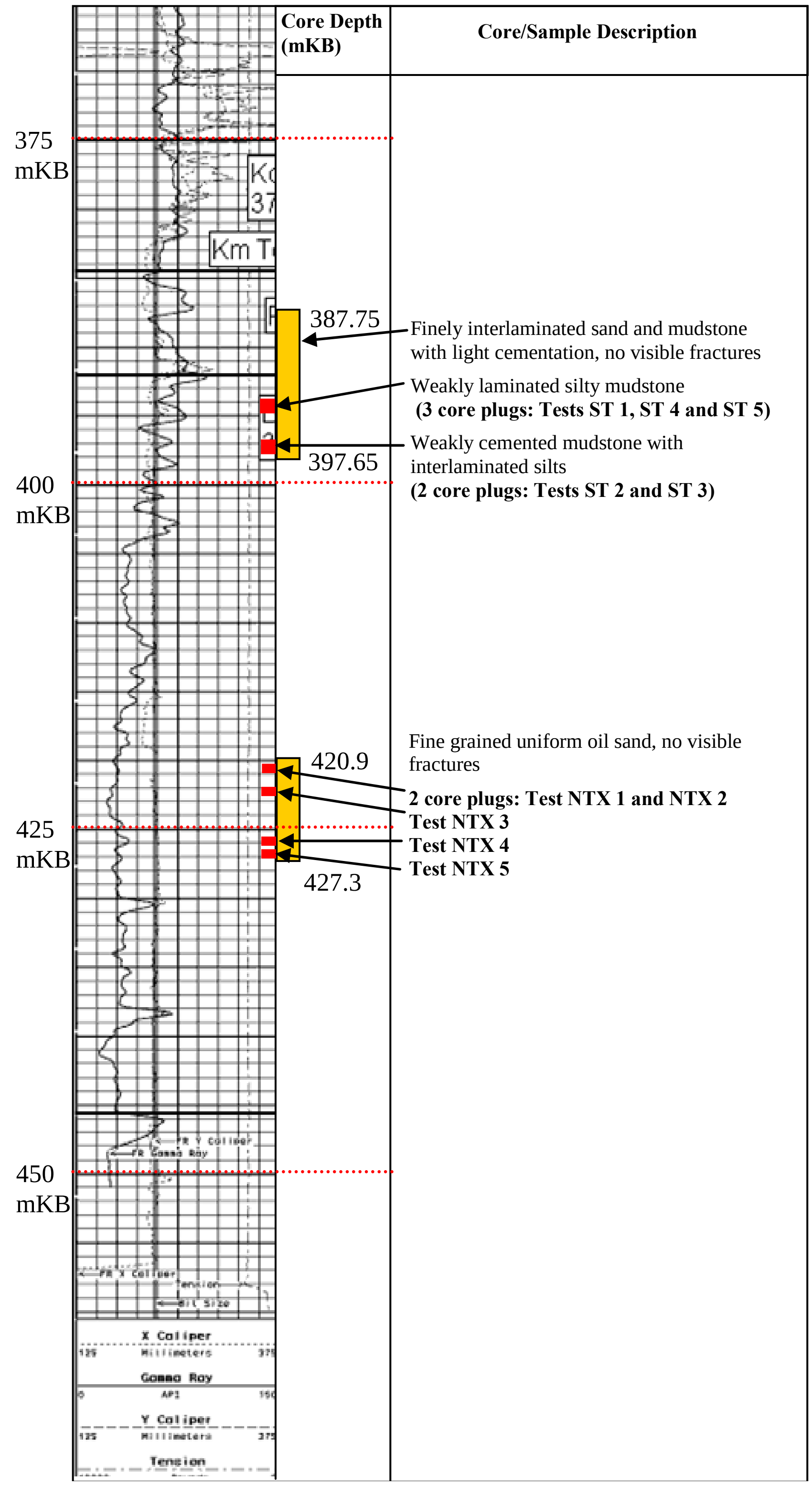

Figure 2.2: Gamma ray log for Paramount well 09-28-78-10W4M in Leismer field, Alberta. Description and location of the viewed cores and the selected samples are also shown in the figure.

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3. CORE SAMPLING AND PRESERVATION

3.1 Overview

AGI personnel made several visits to CoreLab (Calgary) to review and select preserved and frozen samples for a geomechanical laboratory testing program. A total of eight unfrozen and four frozen cores from wells Paramount Leismer 09-28-78-10W4M and 03-03-79-10W4M were examined and the best quality samples were selected. Each core was 75 cm long and was contained in an aluminum sleeve sealed with end caps. After careful examination to assess their overall quality, the cores were photographed and lithological descriptions were made. The cores were 8.9 cm (3.5 in) diameter and were generally in good condition with a few visible minor cracks.

Eighteen unfrozen core sections from interbedded mudstone and shale intervals were selected by AGI for wax preservation which was undertaken by CoreLab immediately after AGI personnel had examined the core. Photographs of unfrozen mudstone samples taken by AGI personnel prior to the wax-preservation are shown in Figure 3.1 and in the U of A report in Appendix B.

For sampling and preserving the frozen oil sand cores, Core Lab personnel used a heat gun to open the aluminium sleeve. The oil sand cores were generally in good condition. The selected oil sand core samples were shipped to the Department of Civil and Environmental Engineering at the U of A under frozen conditions and were kept frozen until the time of testing. Photographs of the frozen samples prior to shipping are shown in Figure 3.2 and in Appendix B.

A brief description of the frozen oil sands and unfrozen wax-preserved interbedded silty mudstone samples used by U of A for geomechanical testing are presented in Table 3.1. Detailed descriptions of all of the samples selected by AGI for preservation are presented in Appendix A. Throughout this report, the interbedded silty mudstone will henceforth be referred to as *mudstone*.

3.2 Sample Descriptions and Petrophysical Properties

As shown in Table 3.1 the oil sands samples selected for testing were mainly fine grained homogeneous oil sands without any visible fractures. Similarly, the mudstone samples were interbedded with fine sand or silt laminations without any fissility. Both the oil sands and mudstone samples had good integrity and did not possess any visible natural fractures.

U of A conducted petrophysical and index property tests on all of the mudstone and oil sand samples on which triaxial tests were conducted. Table 3.2 summarizes these tests.

Figure 3.1: Unfrozen mudstone core samples (SC # 3 and SC # 5) prior to core plug drilling for geomechanical testing. Paramount Leismer 09-28-78-10W4M.

Figure 3.2: Frozen oil sands core samples (SC # 21 and SC # 27) prior to core plug drilling for geomechanical testing. Paramount Leismer 09-28-78-10W4M.

Table 3.1: Summary of full diameter unfrozen wax-preserved interbedded mudstone and frozen oil sands core samples selected for laboratory testing, Paramount Leismer 09-28-78-10W4M.

Sample ID	Core Interval Top Depth (mKB)	FD Core Length (cm)	Lithology	Core Plugs for Testing	Description
SC3	394.56	15	silty mudstone	√	Weakly laminated silty mudstone without fissility or fractures
SC4	394.71	20	silty mudstone	√ √ (2 tests)	Weakly laminated silty mudstone without fissility or fractures
SC5	397.50	15	silty mudstone	√	Weakly cemented mudstone with inter-laminated silts without visible natural fractures
SC6	397.65	20	silty mudstone	√	Weakly cemented mudstone with inter-laminated silts without visible natural fractures
SC21	420.90	25	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC22	421.15	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC25	422.50	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC27	426.00	24	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC30	427.30	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample

FD = full diameter

For all of the mudstone and oil sands samples, U of A also conducted particle size analyses. These results are shown in Figures 31 and 32 of the U of A report in Appendix B. Their Figure 31 shows a poorly graded grain size distribution in the oil sands samples with most of the particles falling in the range of very fine to fine sand. The samples typically had a very low fines content, (particles < 4μm), between 1% and 4%. The grain size distribution curves of the mudstone samples are presented in Figure 32. Appendix B shows between 4% and 22% clay sized fraction (< 4 μm) with most of the particles falling in the silt-sized class.

Based on the Atterberg limits test conducted on the mudstone samples, and using the Unified Soil Classification System (USCS), the mudstone samples ST1, ST2, ST3 and ST6 are classified as low plasticity inorganic clay (CL). Samples ST4 and ST5 are classified as inorganic clay without plasticity, according to USCS. See Figure 33 in Appendix B for the USCS classification of the tested mudstones.

Refer to U of A laboratory test report in Appendix B for a detailed description of petrophysical and index properties of the oil sands and mudstone samples tested in this program.

Table 3.2: Petrophysical and index properties of mudstone and oil sands samples from Paramount Leismer 09-28-78-10W4M. Data from U of A, 2005.

Mudstone									
Test No.	**Core No.**	**Top Depth (mKB)**	**G_s**	**W_L (%)**	**W_P (%)**	**I_P (%)**	**S_w (%)**	**W_N (%)**	**Porosity (%)**
ST1	SC3	394.56	2.68	25.8	15.7	10.1	*	*	20.6
ST2	SC5	397.5	2.67	29.8	16.0	13.8	91.0	9.9	20.8
ST3	SC6	397.65	2.61	32.4	15.2	17.3	91.1	9.8	20.4
ST4	SC4	394.71	2.67	nil	nil	nil	91.5	9.3	19.8
ST5	SC4	394.71	2.67	nil	nil	nil	91.5	9.3	20.6
ST6	SC6	397.65	2.61	32.4	15.2	17.3	91.1	9.8	20.4
Mean			**2.65**	**30.1**	**15.5**	**14.6**	**91.2**	**9.6**	**20.4**
Standard Deviation			**0.03**	**3.1**	**0.4**	**3.4**	**0.2**	**0.3**	**0.3**
Oil Sands									
Test No.	**Core No.**	**Top Depth (mKB)**	**G_s**	**Bulk Volume (%)**			**Porosity (%)**	**Pore Volume (%)**	
				Bitumen	**Sand**	**Water**		**Bitumen**	**Water**
NTX1	SC21	420.9	2.67	15.8	82.7	1.5	25.9	91.3	8.7
NTX2	SC22	421.15	2.67	15.4	82.5	2.2	36.2	87.7	12.3
NTX3	SC25	422.5	2.67	15.2	83.5	1.3	24.5	91.9	8.1
NTX4	SC27	426.0	2.68	14.5	83.0	2.5	35.4	85.4	14.6
NTX5	SC30	427.3	2.68	16.5	81.2	2.3	36.7	87.9	12.1
Mean			**2.67**	**15.5**	**82.6**	**2.0**	**31.7**	**88.8**	**11.2**
Standard Deviation			**0.01**	**0.8**	**0.9**	**0.5**	**6.0**	**2.7**	**2.7**

Note: * tests were not conducted
G_s: specific gravity; W_L, W_P, I_P, S_w, and W_N are liquid limit, plastic limit, plasticity index, water saturation and natural water content, respectively.

4. UNIVERSITY OF ALBERTA LABORATORY TESTING PROGRAM

4.1 Introduction

All the triaxial tests were conducted by U of A at room temperature (21°C) following standard testing procedures. Oil sands and mudstone core plugs were tested using isotropically consolidated drained and undrained active compression stress paths, respectively.

A total of five isotropically consolidated drained (CID) triaxial compression tests were conducted on oil sands samples. The first and the second triaxial tests were conducted on identical thawed core plugs on bitumen-extracted and non-extracted oil sands samples, respectively. The next three oil sands tests were conducted on bitumen-extracted oil sands samples. All of the oil sands samples were sheared under drained conditions. Steady-state permeability measurements were made before shearing, just before the peak strength and at residual strength. See Table 4.1 and Appendix B for details about sample identification, test condition and pre- and post-peak sample photographs.

A total of six isotropically consolidated undrained (CIU) triaxial compression tests at various confining stresses with pore pressure measurements were also conducted by U of A on mudstone core plugs. Steady-state permeability measurements were made on the mudstone samples at residual shearing conditions after failure. The diameter and height of the tested core plugs were 63 mm and 127 mm, respectively. See Table 4.1 and Appendix B for details about sample identification, test conditions and pre- and post-peak sample photographs.

For all of the triaxial tests, the U of A used a simulated brine solution with a salinity of 3000 ppm for sample saturation and back pressure. The salinity of the brine solution was chosen by U of A based on their previous work conducted on the Clearwater Formation clay shale. NaCl was used to prepare the salt solution.

4.2 Summary of Results

The stress-strain behaviour, elastic properties, and peak and residual strength parameters were determined from the triaxial compression tests conducted at various effective confining stresses for each of the oil sands and the mudstone samples. Figure 4.1 and 4.2 show bulk compressibilities of the oil sands and mudstone samples during isotropic loading-unloading tests conducted prior to triaxial shearing. For both lithologies, bulk compressibility is a strong function of effective confining stress especially below an effective stress of 1.5 MPa.

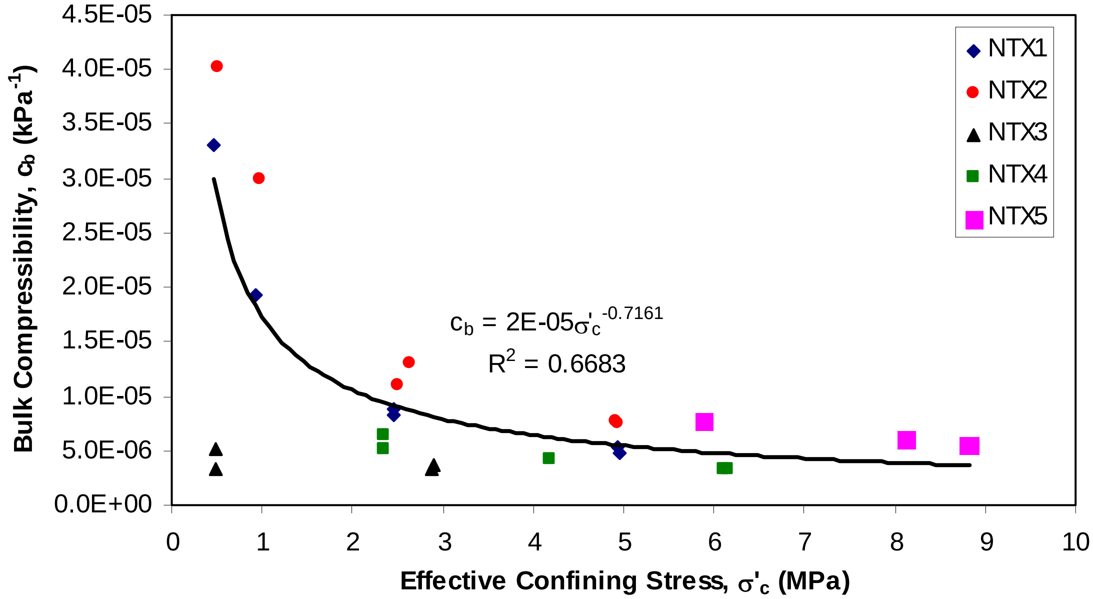

Figure 4.1: Bulk compressibility of oil sands samples as a function of effective confining stress during isotropic loading unloading tests.

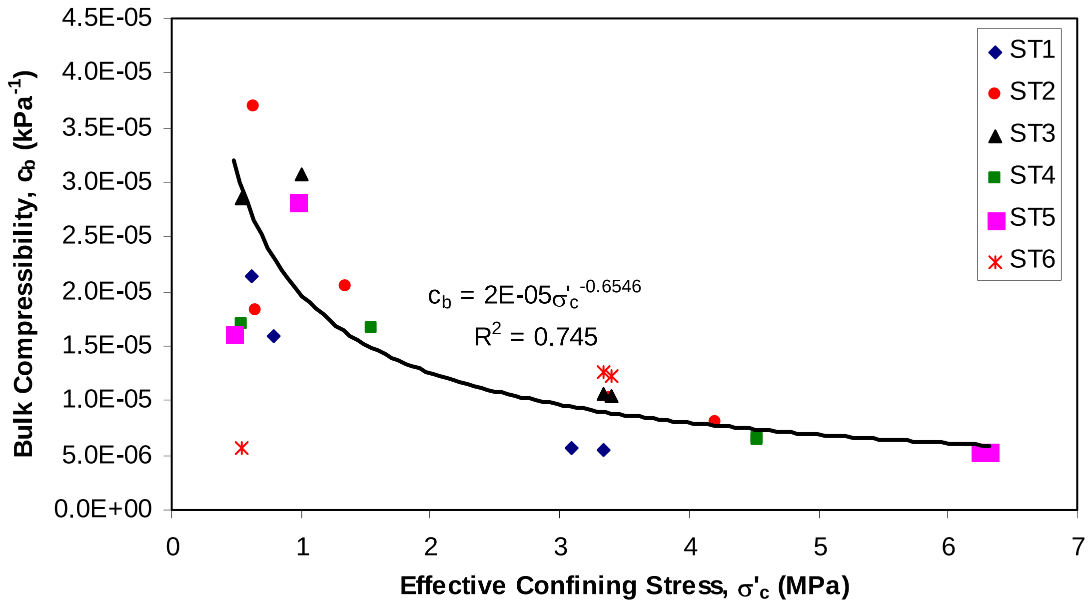

Figure 4.2: Bulk compressibility of mudstone samples as a function of effective confining stress during isotropic loading unloading tests.

A summary of the static mechanical properties of the Leismer oil sands and mudstone samples is presented in Table 4.2. The Young's modulus and the Poisson's ratio for samples reported in Table 4.2 were determined from the initial linear portions of the axial stress difference versus axial strain curves and the radial strain versus axial strain curves, respectively. These parameters were typically determined up to an initial axial strain of 0.1%. The stress-strain data obtained for all of the triaxial tests on the oil sands and the mudstone samples are included in U of A's report in Appendix B.

Table 4.1: Summary of test conditions for triaxial testing of mudstone and oil sands samples. Paramount Leismer 09-28-78-10W4M.

Test No.	Core No.	Top Depth (mKB)	Initial Cyclic Compression Stress Range (MPa)	Pre-shear Effective Confining Stress (MPa)	Bitumen Extracted?
Mudstone					
ST1	SC3	394.56	0.05 - 3.34	0.71	na
ST2	SC5	397.5	0.05 - 4.21	1.06	na
ST3	SC6	397.65	0.05 - 3.39	0.96	na
ST4	SC4	394.71	0.05 - 4.53	4.53	na
ST5	SC4	394.81	0.05 - 6.33	6.35	na
ST6	SC6	397.75	0.05 - 3.39	0.56	na
Oil Sands					
NTX1	SC21	420.9	0.05 - 4.95	2.44	yes
NTX2	SC22	421.15	0.05 - 4.94	2.47	no
NTX3	SC25	422.5	0.05 - 2.9	0.49	yes
NTX4	SC27	426.0	0.05 - 6.16	4.37	yes
NTX5	SC30	427.3	0.05 - 8.83	8.11	yes

na: not applicable

The initial static Young's moduli range from 0.24 to 1.19 GPa for the oil sands and 0.27 to 2.11 GPa for the mudstones, over a range of confining stresses. Poisson's ratio for the oil sands ranges from 0.25 to 0.32. For the mudstones, Poisson's ratio was not calculated because the net volume change is zero during undrained triaxial shearing which leads to a Poisson's ratio of 0.5.

The strength properties of the mudstone and oil sands samples were analysed using Mohr-Coulomb and Hoek-Brown failure criteria. Both the peak and residual strength analyses were conducted using the software RocData v.3 from Rocscience Inc. (2003). The Mohr-Coulomb failure criterion is a linear failure envelope drawn tangent to a series of Mohr circles on a plot of shear stress versus effective normal stress. It is commonly used to describe the strength properties of intact rocks. Since the stress-strain and strength behaviour of many rocks is known to be non-linear and confining stress-dependent, the Hoek-Brown failure criteria was also used to analyse the laboratory strength data.

Table 4.2: Summary of static mechanical properties of McMurray Formation mudstones and oil sands determined from triaxial tests, Paramount Leismer 09-28-78-10W4M. Data from U of A, 2005.

Sample No.	Depth of Top of Sample (mKB)	Pore Pressure at Peak Strength (MPa)	Pore Pressure at Residual Strength (MPa)	Confining Stress (MPa)	Effective Peak Axial Stress (MPa)	Effective Axial Stress at Residual Strength (MPa)	Initial Static Young's Modulus (GPa)*	Initial Static Poisson's Ratio*
Mudstone								
ST1	394.56	1.18	0.42	2.57	7.81	7.74	0.556	na
ST2	397.5	0.96	0.33	2.91	11.08	7.15	0.274	na
ST3	397.65	1.18	0.54	3.00	12.99	11.35	0.778	na
ST4	394.71	2.96	1.70	6.53	27.15	20.17	2.114	na
ST5	394.81	3.28	1.95	8.35	31.29	27.79	1.829	na
ST6	397.75	1.51	0.87	2.57	6.69	6.15	2.018	na
Oil Sands								
NTX1	420.9	1.10	1.01	3.44	12.24	10.02	1.195	0.25
NTX2	421.15	1.00	1.02	3.67	11.59	10.35	1.180	0.25
NTX3	422.5	0.95	0.95	1.42	2.83	2.30	0.715	0.25
NTX4	426.0	1.02	1.00	5.34	15.44	14.63	0.320	0.25
NTX5	427.3	1.00	1.00	9.08	21.77	27.80	0.240	0.32

Note: * calculated at 0.1% axial strain
na not applicable since Poisson's ratio is 0.5 for undrained tests.

The Mohr-Coulomb analyses for peak and residual strengths of the mudstone samples are presented in Figures 4.3 and 4.4, and for the oil sands samples in Figures 4.5 to 4.6. Table 4.3 summarizes the failure criteria results for peak and residual triaxial test data on all the samples.

Table 4.3: Summary of Mohr-Coulomb and Hoek-Brown parameters fit to the laboratory test data from the McMurray Formation mudstones and oil sands.

Mohr-Coulomb		**Cohesion (MPa)**		**Friction Angle**	**Residuals**
mudstone	peak	0.17		47°	20
	residual	0.0		39°	17
oil sands	peak	0.7		32°	7
	residual	0.4		32°	3
Hoek-Brown		**UCS (MPa)**	**m**	**s**	**-**
mudstone	peak	2.11	12.6	1	62
	residual	0.73	6.9	1	164
oil sands	peak	0.53	6.5	1	6
	residual	0.66	6.6	1	23

'm' and 's' are empirical constants in the Hoek-Brown criteria

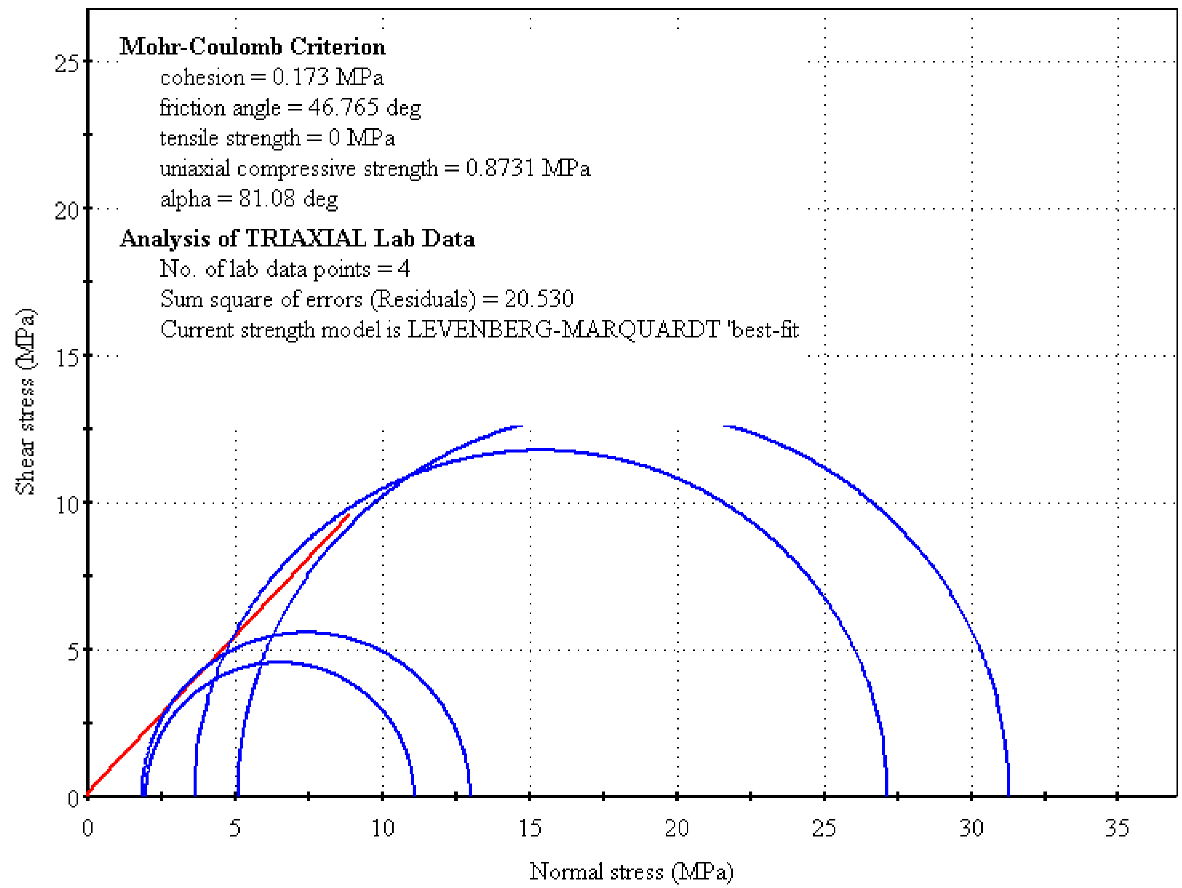

Figure 4.3: Mohr-Coulomb failure envelope fit to peak triaxial test results on McMurray Formation mudstone samples from Paramount Leismer 09-28-78-10W4M (depth range: 394.56 mKB to 397.75 mKB). Data from U of A (2005)

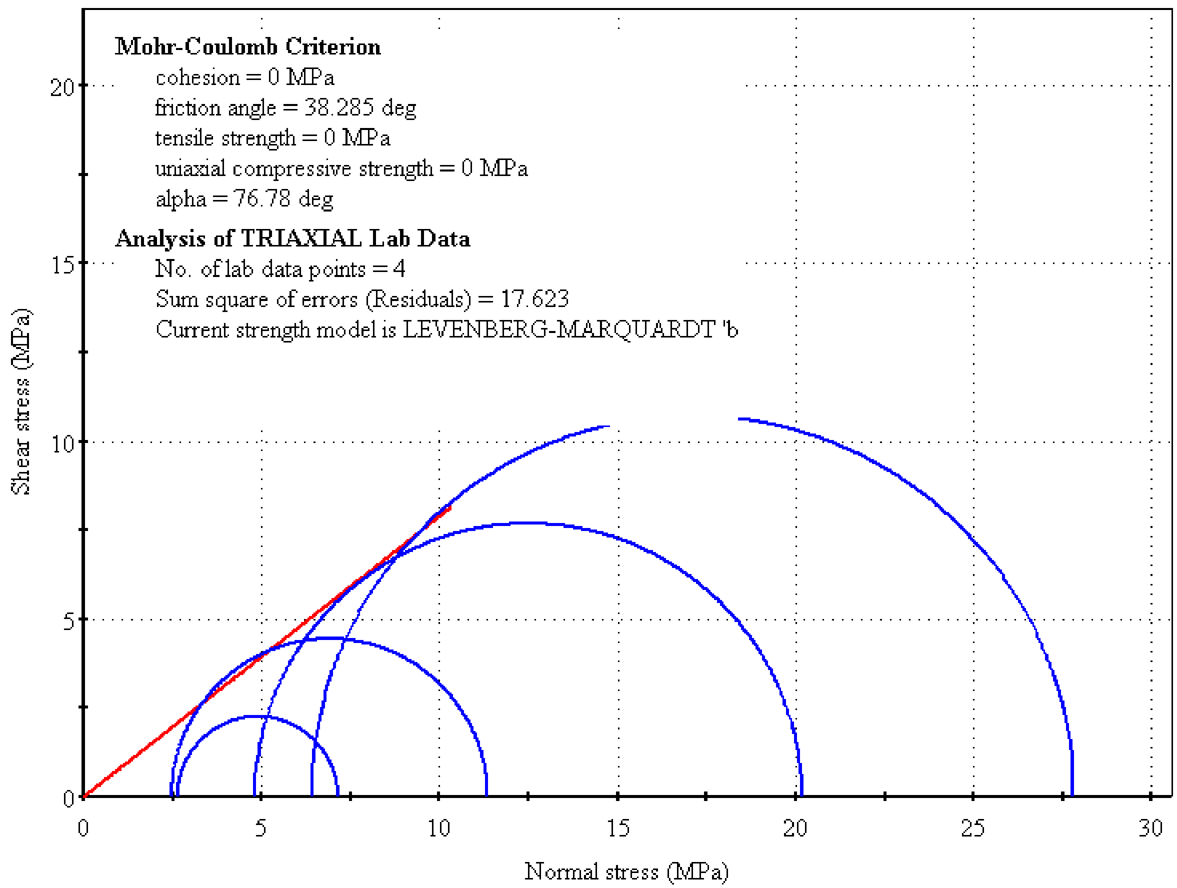

Figure 4.4: Mohr-Coulomb failure envelope fit to residual triaxial test results on McMurray Formation mudstone samples from Paramount Leismer 09-28-78-10W4M (depth range: 394.56 mKB to 397.75 mKB). Data from U of A (2005)

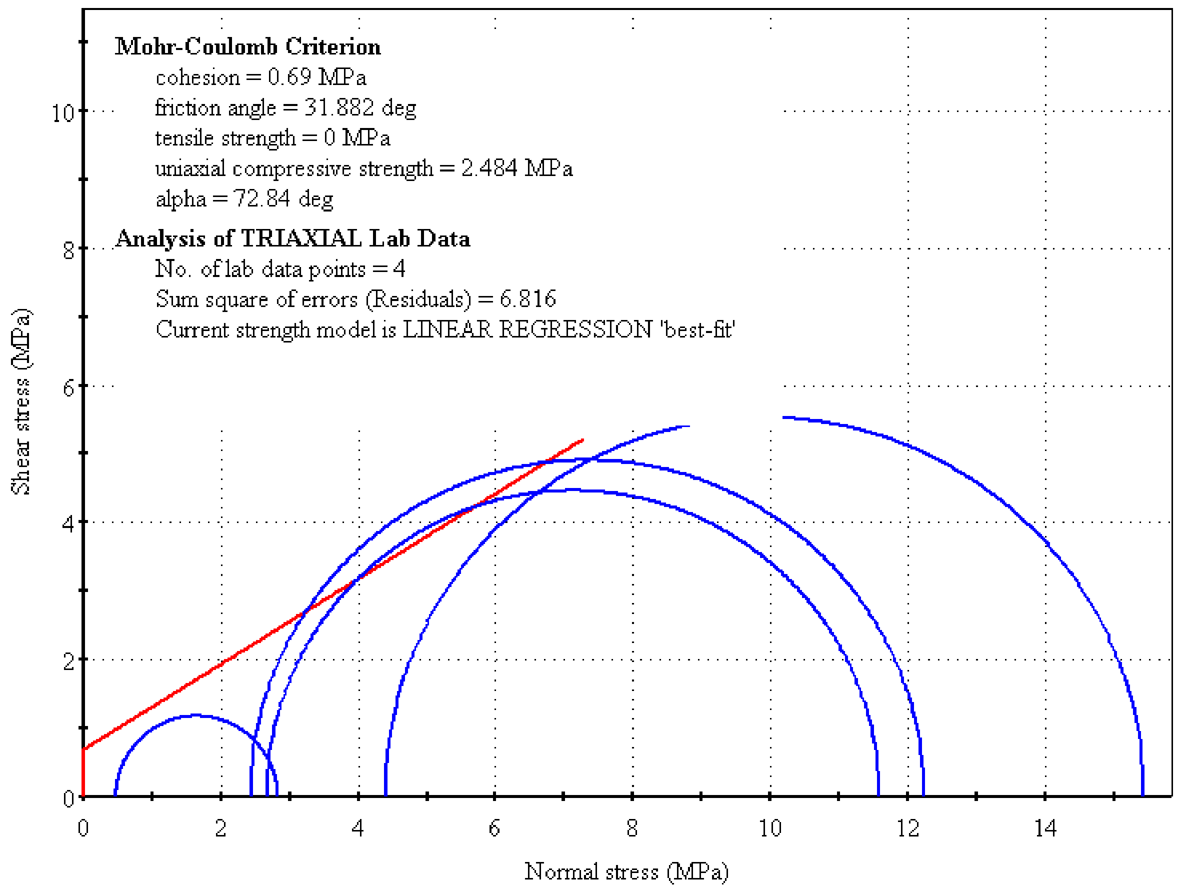

Figure 4.5: Mohr-Coulomb failure envelope fit to peak triaxial test results on McMurray Formation oil sands samples from Paramount Leismer 09-28-78-10W4M (depth range: 420.9 mKB to 427.3 mKB). Data from U of A (2005)

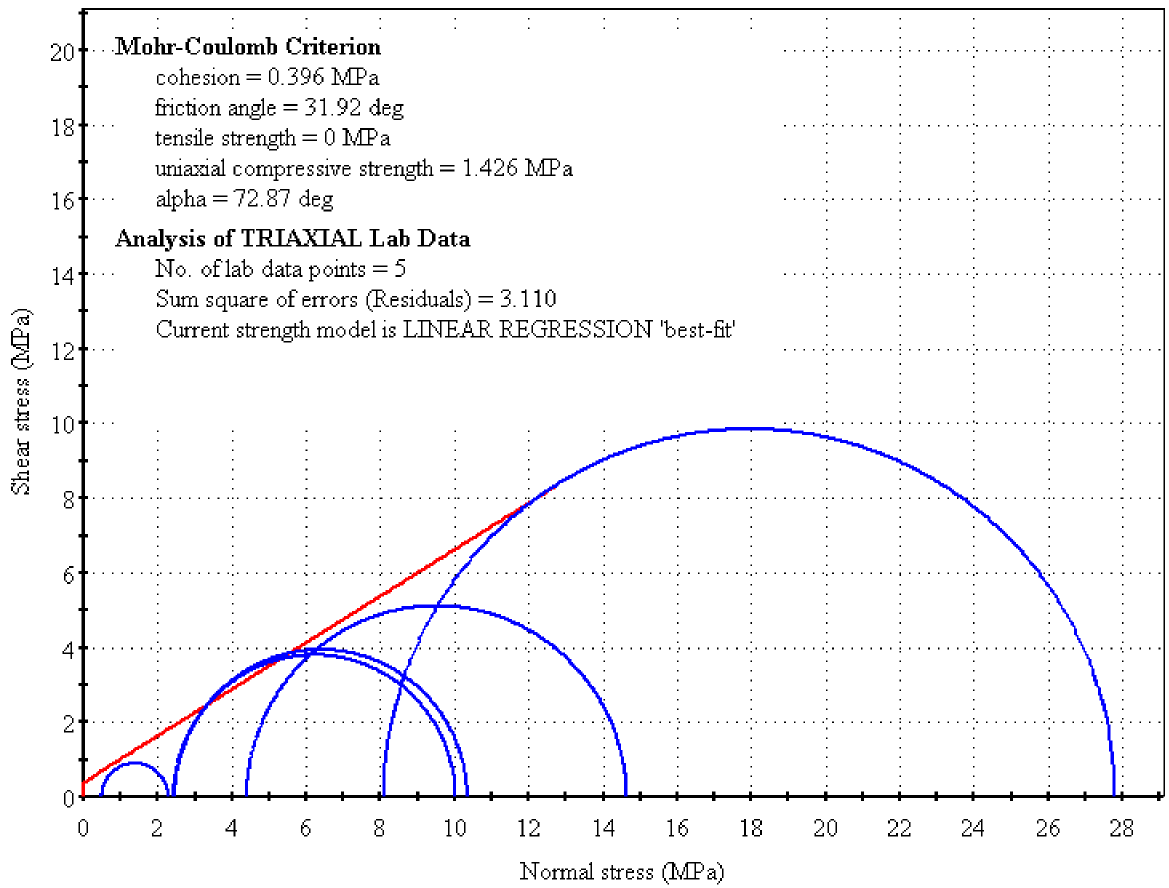

Figure 4.6: Mohr-Coulomb failure envelope fit to residual triaxial test results on McMurray Formation oil sands samples from Paramount Leismer 09-28-78-10W4M (depth range: 420.9 mKB to 427.3 mKB). Data from U of A (2005)

4.3 Analysis and Interpretation

As can be seen from the peak and residual failure envelope plots for the mudstones in Figures 4.3 and 4.4, the Mohr-Coulomb criteria provides a good fit for the both peak and residual data, based on the residuals.

The peak and residual strength data for the mudstones exhibit relatively low cohesion and high friction angles, typical of granular materials. The residual friction of 39° indicates substantial frictional resistance to shear deformation once the peak strength is exceeded. In the oil sands the post-peak shearing caused a decrease in cohesion but at the same friction angle. The same residual friction angle as that of the peak indicates that the initial sample may have been disturbed or at a residual state to begin with.

The stress-strain behaviour of the mudstones and the excess pore pressure that developed in the samples during undrained triaxial shearing are shown in Figures 4.7 and 4.8. The results show that all of the mudstone samples exhibited brittle behaviour and with a post-peak residual strength.

The stress-strain and volume change behaviour of the oil sands during drained triaxial shearing are shown in Figure 4.9 and 4.10. The oil sands samples show brittle to ductile behaviour with increasing effective confining stress. Both the peak and residual strength increase with increasing effective confining stress.

As shown in Figure 4.10, the volume change behaviour of the oil sands is a strong function of the applied effective confining stress. As illustrated by tests NTX1 to NTX3, the oil sands samples tested at relatively lower effective confining stresses (up to 2.6 MPa) show a small pre-peak contraction followed by post-peak dilation. Furthermore, with decreasing effective confining stress, the magnitude of volumetric contraction decreases and dilation increases. The oil sands samples tested at higher effective confining stresses (NTX4: 4.4 MPa and NTX5: 8.7 MPa) show volumetric contractile behaviour throughout shearing to the residual strength. Two identical oil sand samples tested with and without bitumen (NTX1 and NTX2) under the similar testing conditions do not show considerable differences in their stress-strain and volume change behaviour.

The pre-and the post-peak dilation angles for the samples vary depending upon their effective confining stress. As shown in Table 4.4, with increasing effective confining stress the pre-peak dilation angle increases while the post-peak dilation angle decreases for the oil sands. Note that in this report a negative dilation angle refers to contractile behaviour, i.e., a volume decrease, compared to a positive dilation angle, which refers to a volume increase.

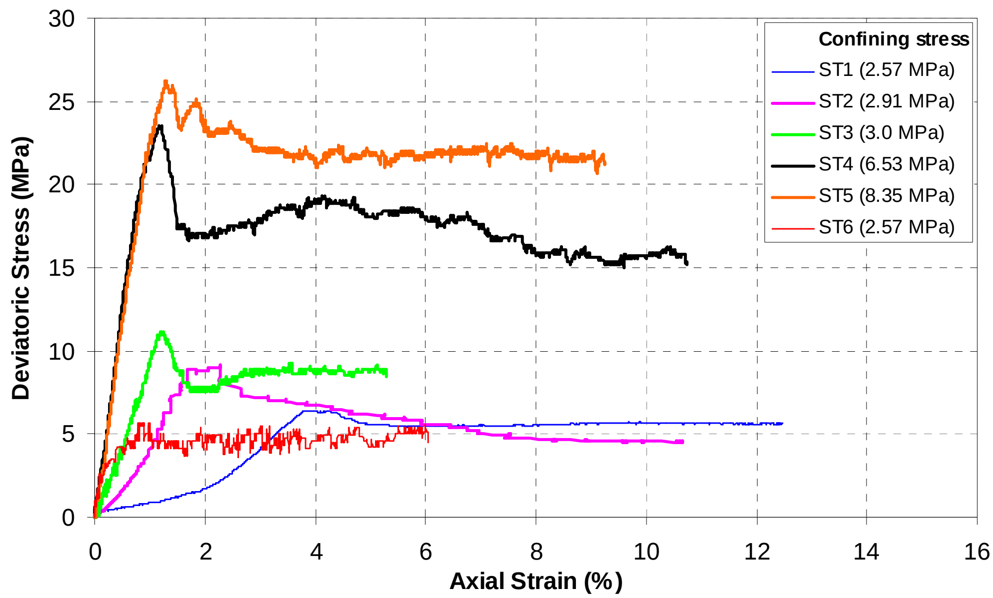

Figure 4.7: Stress-strain behaviour of McMurray Formation mudstone samples from Paramount Leismer 09-28-78-10W4M (depth range: 394.56 mKB to 397.75 mKB) during undrained triaxial tests. Data from U of A (2005).

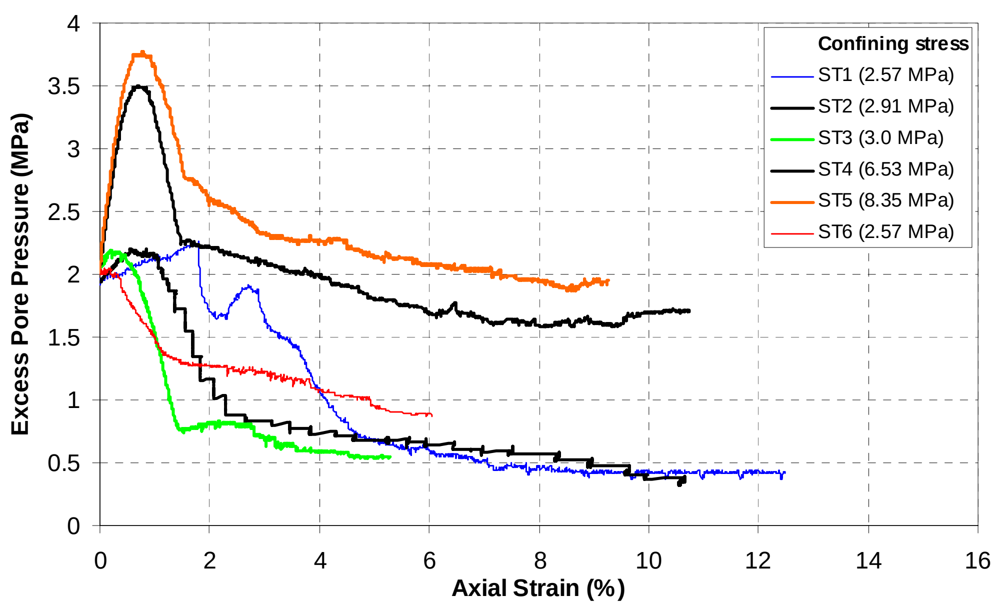

Figure 4.8: Excess pore pressure development as a function of axial strain in McMurray Formation mudstone samples from Paramount Leismer 09-28-78-10W4M (depth range: 394.56 mKB to 397.75 mKB) during undrained triaxial tests. Data from U of A (2005).

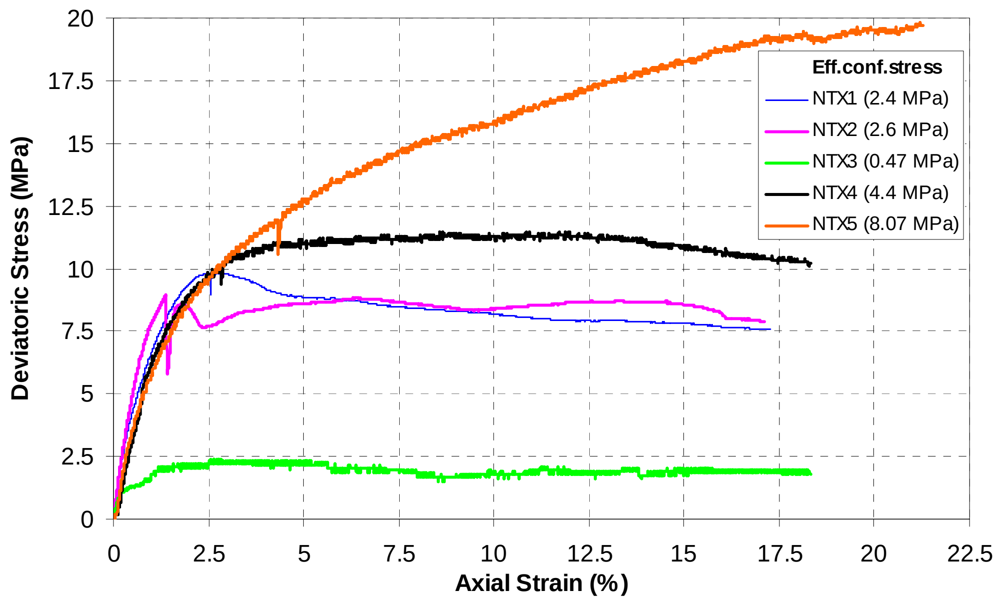

Figure 4.9: Stress-strain behaviour of McMurray Formation oil sands samples from Paramount Leismer 09-28-78-10W4M (depth range: 420.9 mKB to 427.3 mKB) during undrained triaxial tests. Data from U of A (2005).

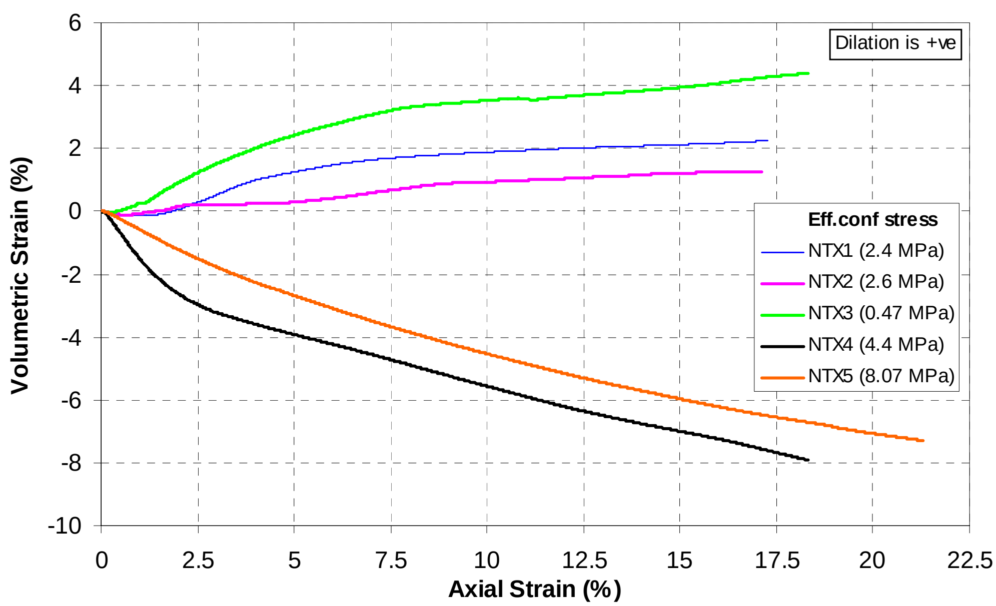

Figure 4.10: Excess pore pressure development as a function of axial strain in McMurray Formation oil sands samples from Paramount Leismer 09-28-78-10W4M (depth range: 420.9 mKB to 427.3 mKB) during undrained triaxial tests. Data from U of A (2005).

Table 4.4: Summary of pre- and post-peak dilation properties and the permeabilities of McMurray Formation oil sands during drained triaxial shearing, Paramount Leismer 09-28-78-10W4M. Data from U of A, 2005.

Sample No.	Depth of Top of Sample (mKB)	Effective Confining Stress (MPa)	Pre-Peak Dilation Angle[1]	Post-Peak Dilation Angle	Initial Permeability[2] to Water (mD)	Pre-Peak Permeability[3] to Water (mD)	Post-Peak Permeability[4] to Water (mD)
NTX1	420.9	2.34	-6.9°	17.8°	87	66	60
NTX2	421.15	2.67	-7.8°	6.9°	0.0689	0.0307	0.0349
NTX3	422.5	0.47	-5.7°	27.4°	261	141	33
NTX4	426.0	4.38	-54.1°	-	78	83	37
NTX5	427.3	8.08	-30.9°	-	259	130	73

1. a negative dilation angle corresponds to volumetric contraction
2. measured after isotropic consolidation
3. measured at or just before peak strength
4. measured at residual strength

The steady-state water permeabilities measured on the oil sand samples before triaxial shearing, but close to peak strength, and at residual strength are shown in Table 4.4. Two identical oil sand samples tested with and without bitumen (NTX1 and NTX2) under similar testing conditions show considerably different water permeability values. The absolute permeability to water measured on the bitumen extracted oil sands sample (NTX1) is considerably higher than the effective permeability measured on the oil sands sample without bitumen extraction (NTX2). Figure 4.11 illustrates the effect of volumetric strain on permeability development in the oil sands during triaxial shearing. All of the oil sands samples show a strong permeability reduction during both post-peak dilation and contraction.

The permeabilities measured on mudstone samples at various strain levels at the post-peak residual condition are illustrated in Figure 4.12. Note the permeability decrease with increasing axial strain during undrained triaxial shearing. Because the net volumetric strain is zero the development of shear planes and the magnitude of slippage on the shear planes reduces the permeability, albeit not significantly.

Exposure of clay-rich mudstones to a saturating fluid which is fresher than their native pore water can induce swelling, especially at effective confining pressures below the rock's swelling pressure. Tests ST1, ST3 and ST6 which were saturated at low effective confining stresses of about 0.5 to 1 MPa might have incurred some swelling during saturation if a significant amount of reactive clay minerals were present in the rock. The swelling generally reduces the strength and stiffness of these shales. In this study, the pore water chemistry and mineralogy of the interbedded mudstones were not determined, therefore no conclusions can be drawn on the effects of the 3000 ppm NaC1 saline solution used to saturate the samples.

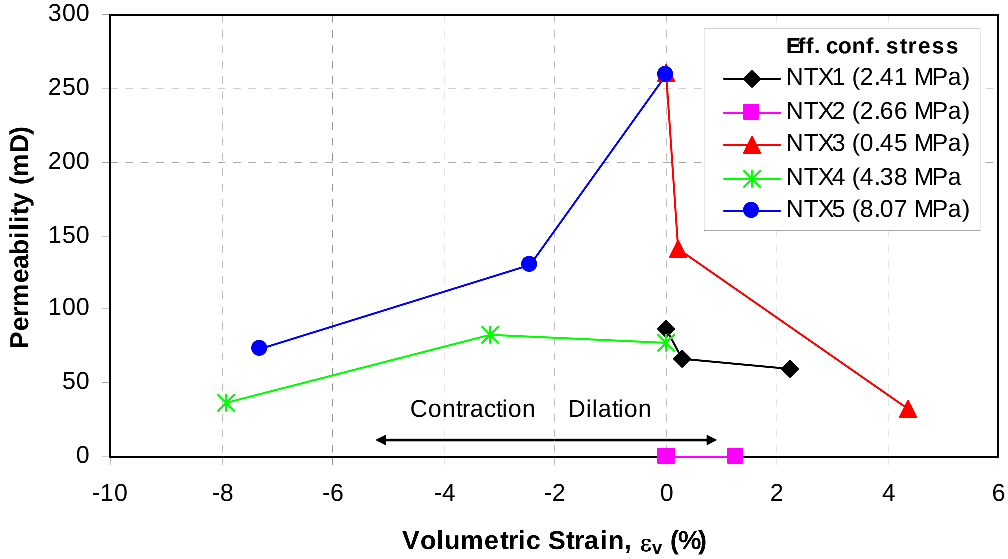

Figure 4.11: Change of permeability (k) as a function of volumetric strain (ε_v) in McMurray Formation oil sands samples measured before shearing, at peak and at post-peak condition in drained triaxial tests. Data from U of A (2005).

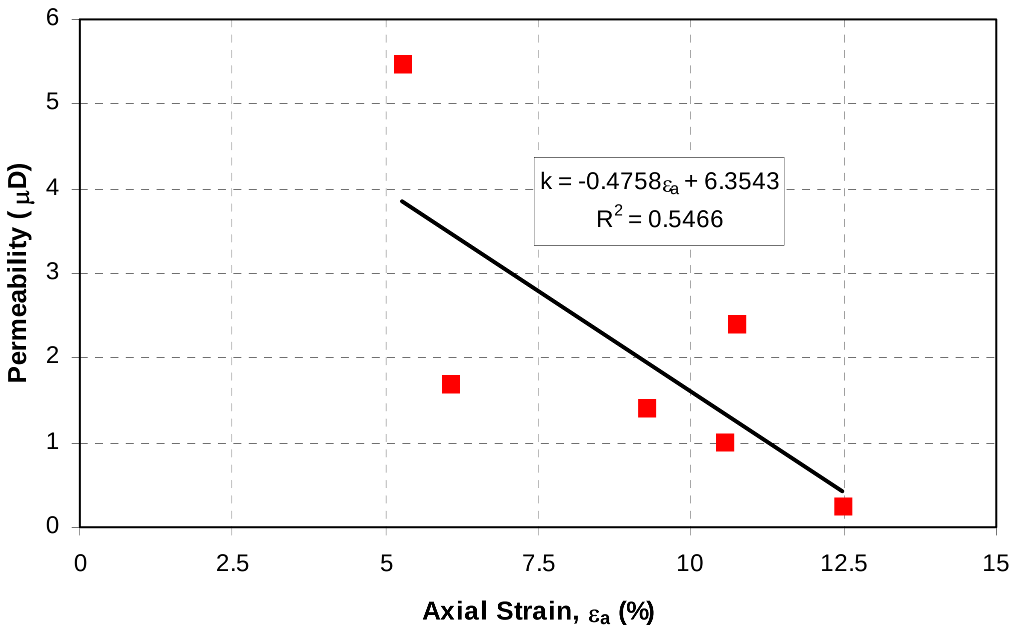

Figure 4.12: Change of permeability (k) as a function of axial strain (ε_a) in McMurray Formation mudstone samples measured at residual strength condition in undrained triaxial tests. Data from U of A (2005).

Table 4.5 gives a comparison between the key parameters assumed in the previous SAGD coupled geomechanical simulation study conducted for NAOSC by AGI in 2004 and the parameters measured in this project. Some of the assumed parameters, shown in yellow shading in the table, differ significantly from the recent laboratory measured values. The differences observed in the measured and the assumed values clearly demonstrate the importance of carrying out representative laboratory tests on the appropriate strata to obtain the parameters required for simulation. Sensitivity studies of several of the input parameters to the SAGD simulation are discussed in AGI's earlier report, e.g. permeability, friction angles and dilation angles.

Table 4.5 Comparison of key geomechanical parameters measured in this laboratory program and those assumed in the earlier coupled reservoir-geomechanical simulation study (AGI, 2004).

Parameters	Oil Sands		Interbedded Mudstone		Comments
	Assumed[1]	Measured[2]	Assumed[1]	Measured[2]	
static Young's modulus, E	816 – 834 MPa	730 MPa	80 MPa	1261 MPa	
static Poisson's ratio, ν	0.3	0.26	0.3	n/a	Poisson's ratio cannot be determined for undrained tests.
peak friction angle, ϕ_p	27°	32°	33°	47°	
residual friction angle, ϕ_r	n/a	32°	10°	39°	Peculiar high residual friction angle.
peak cohesion, c_p	0.0 MPa	0.0 MPa	0.1 MPa	0.17 MPa	
residual cohesion, c_r	0.0 MPa	0.0 MPa	0.0 MPa	0.0 MPa	
peak dilation angle, ψ_p	3.3°	6.6° – 54.1°	10°	n/a	Dilation angle of mudstone cannot be determined because of undrained shearing.
residual dilation angle, ψ_r	n/a	6.9° – 27.4°	0.0°	n/a	
steady-state permeability to water, k_w	1500 – 3000 mD	0.07 - 259 mD	0.0001 mD	0.00026 - 0.0055 mD	Measured values are range of values before shearing and at residual strength.
porosity	31 – 34 %	31.7 %	10 %	20.4 %	
pore volume compressibility	$5x10^{-6}$ kPa^{-1}	$2.86x10^{-5}$ kPa^{-1}	$5x10^{-6}$ kPa^{-1}	$8.6x10^{-5}$ kPa^{-1}	PVC calculated using bulk compressibility data obtained during isotropic compression cycles.

1. Values assumed for the Upper and Lower McMurray reservoirs from the previous simulation study (AGI, 2004).
2. Average laboratory measured values in this study.
3. The measured values which differ 30% or more from those the assumed are highlighted in yellow.
   n/a not applicable

5. REFERENCES

Proprietary References

Advanced Geotechnology Inc., **Coupled SAGD Reservoir-Geomechanical Simulation Study, Keyhole Area, Northeast Alberta**. Proprietary report prepared for North American Oil Sands Corporation, AGI File 10-247, October 2004.

University of Alberta., Department of Civil and Environmental Engineering, Petroleum Geomechanics Testing Group, **Geomechanical Testing Program, Oil Sands and Interbedded Mudstones, Leismer, Alberta, Paramount Leismer 09-28-78-10W4M,** Prepared by Dr. Rick Chalaturnyk for Advanced Geotechnology Inc./ North American Oil Sands Corporation, Received November 23, 2005**.**

Public Domain References

RocScience Inc., **RocData**, Version 3, Toronto, Ontario, 2003.

APPENDIX A

Core Descriptions

Paramount Leismer 09-28-78-10W5

Paramount Leismer 03-03-79-10W4

Table A.1: Description of selected full diameter unfrozen interbedded mudstone and shale core samples preserved in wax. Core plugs obtained for testing of selected cores as indicated.

Sample ID	Core Interval Top Depth (mKB)	Core Length (cm)	Lithology	Core Plugs for Testing	Description
Well ID: Paramount Leismer 09-28-78-10W4M					
SC1	387.89	21	Inter-laminated sand and mudstone		Finely interlaminated sand and mudstone with light cementation and no visible natural fractures
SC2	388.10	17	Inter-laminated sand and mudstone		Finely interlaminated sand and mudstone with light cementation and no visible natural fractures
SC3	394.56	15	silty mudstone	√	Weakly laminated silty mudstone without fissility or fractures
SC4	394.71	20	silty mudstone	√ √ (2 tests)	Weakly laminated silty mudstone without fissility or fractures
SC5	397.50	15	silty mudstone	√	Weakly cemented mudstone with inter-laminated silts without visible natural fractures
SC6	397.65	20	silty mudstone	√	Weakly cemented mudstone with inter-laminated silts without visible natural fractures
Well ID: Paramount Leismer 03-03-79-10W4M					
SC7	406.22	17	shale		Very fissile shale with numerous bedding-parallel hairline cracks
SC8	406.39	12	shale		Very fissile shale with numerous bedding-parallel hairline cracks
SC9	406.51	9	shale		Very fissile shale with numerous bedding-parallel hairline cracks
SC10	406.95	10	shale		Fissile shale without fractures
SC11	407.27	19	shale		Fissile shale without fractures
SC12	407.46	22	siltstone		Cemented siltstone
SC13	411.45	20	Laminated oil sand		Extremely weak oil sand with shale laminations
SC14	411.65	20	Laminated oil sand		Extremely weak oil sand with shale laminations
SC15	411.85	20	Laminated oil sand		Extremely weak oil sand with shale laminations
SC16	412.05	12	Laminated oil sand		Extremely weak oil sand with shale laminations
SC17	413.05	20	Inter-laminated shale and oil sand		Interlaminated shale and oil sand without visible fractures
SC18	413.25	20	Inter-laminated shale and oil sand		Inter-laminated shale and oil sand without visible fractures

Table A.2: Decscription of selected full diameter frozen oil sand core samples. Core plugs obtained for testing of selected cores are indicated.

Sample ID	Core Interval Top Depth (mKB)	Core Length (cm)	Lithology	Core Plugs for Testing	Description
Well ID: Paramount Leismer 09-28-78-10W4M					
SC19	420.20	20	oil sand		Fine grained uniform oil sand with possible vertical fractures, extent of fractures into the core unknown
SC20	420.65	25	oil sand		Fine grained uniform oil sand with possible vertical fractures, extent of fractures into the core unknown
SC21	420.90	25	oil sand	√ √ (2 tests)	Fine grained uniform oil sand without any visible fractures, good sample
SC22	421.15	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC23	422.10	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC24	422.30	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC25	422.50	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC26	422.90	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC27	426.00	24	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC28	426.56	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC29	426.76	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC30	427.30	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample

APPENDIX B

University of Alberta Testing Report

"Geomechanical Testing Program for Oil Sands and Interbedded Mudstones, Leismer, Alberta"

Received November 23, 2005

North American Oil Sands Corporation

Geomechanical Testing Program
for
Oil Sands and Shales
Leismer, Alberta

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October, 2005

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report provides the detailed results of a laboratory program completed on shale for determination of strength properties and thermal expansion behavior. The main objective was to characterize the material and to determine typical strength properties for use in design/analysis.

Oil sands core was obtained from well 09-28-78-10W4M over the depth intervals 420 m to 427 m and interbedded mudstone/oil sands core was obtained from wells 03-03-79-10W4M and 09-28-78-10W4M over the depth intervals 387.8 m to 413 m. All oil sands samples were delivered to the University of Alberta in a frozen state while the interbedded mudstone/oil sands specimens arrived unfrozen and preserved in plastic wrap and wax. The oil sands samples were placed in frozen storage (-25 ^{o}C) until required for testing and all interbedded mudstone samples were placed in a controlled temperature/humidity core storage room until required for testing.

The laboratory program included material characterization tests (Atterberg limits, grain size distribution, and specific gravity), and triaxial shear strength tests. All oil sands specimens were tested under drained triaxial compression conditions while the interbedded mudstone/oil sands specimens were tested under undrained triaxial compression conditions. Permeability tests were conducted on both the bitumen extracted oil sands and the interbedded mudstone/oil sands specimens. One permeability test was conducted on a bitumen saturated oil sands specimen to measure the effective permeability to water.

The following summarizes the <u>average</u> characteristics of the oil sands specimens that were tested; porosity ~ 35.7%; % clay fraction ~ 1.5 % and dry density ~ 1.72 g/cm^3 . The average bitumen saturation was 89% (of pore volume). The average bulk modulus value was K = 624 MPa. The average Young's modulus was 730 MPa and Poisson's ratio was 0.25. These moduli values are all confining stress dependent. The peak and residual Mohr-Coulomb strength parameters were: c'_{peak} = 0 MPa and ϕ'_{peak} = 42^{o} ; and c'_{res} = 0 MPa and ϕ'_{res} = 37^{o} , respectively. On average, all the oil sands specimens exhibited a reduction in absolute permeability following shear failure, in some cases as large as a 72% reduction in absolute permeability.

All the interbedded mudstone/oil sands specimens were sheared under undrained compression conditions. The specimens exhibited a strain softening, dilatant volume change stress-strain response indicated by decreasing pore pressure during shear. The following summarizes the <u>average</u> characteristics of the interbedded mudstone/oil sands specimens that were tested; moisture content ~ 9.5%; porosity ~ 20.6%; % clay fraction ~ 10 to 15 % and dry density ~ 2.11 g/cm^3 The plastic and liquid Atterberg limits were 15.5% and 30.1%, respectively. The fine grained components of the samples were classified as low plastic, inorganic clay. The peak and residual Mohr-Coulomb strength parameters were: c'_{peak} = 0 MPa and ϕ'_{peak} = 46^{o}; and c'_{res} = 0 MPa and ϕ'_{res} = 37^{o}, respectively.

No clear relationship was found for the post-test permeability results conducted on the interbedded mudstone/oil sands specimens. On average, the post-shear permeability was approximately 2 μD. This is a very small permeability and suggests that throughout the shear process, no discrete discontinuities are created within these specimens that enhance the permeability substantially. It would be prudent to conduct a series of tests both pre- and post-shear if not during the shearing process (for drained shear tests) to fully understand the evolution of permeability within this class of materials.

1. INTRODUCTION

The objective of the testing program was to determine the strength, deformation and permeability properties of selected oil sand and shale samples obtained from a new well in the Leismer area, Alberta in early March 2005. These data are required to use as input parameters for geomechanical reservoir simulation and to understand the geomechanical behaviour of the particular oil sands and shales during SAGD operations.

2. CORE DESCRIPTION

2.1. Core Arrival at UofA

Figure 1 illustrates the state of oil sands core and shale core upon arrival at the University of Alberta. All oil sands core specimens arrived in a completely frozen state with dry ice remaining in the coolers. Additional dry ice was added to the coolers and placed in freezer storage. The storage temperature was -25 ^{o}C. All shale samples were also received in excellent condition and were placed in a moisture room until required for testing.

a)

b)

Figure 1. State of a) oil sands and b) shale specimens upon arrival at the University of Alberta

2.2. Specimen Selection

Prior to sending core specimens to the University of Alberta, AGI had described and photographed and identified each sample with a particular reference number. Table 1 provides the descriptions, as completed by AGI, for these oil sands samples. Table 2 provides descriptions for the interbedded mudstone/oil sands samples. **Note that for brevity, these interbedded mudstone/oil sands samples will be referred to as "shale" samples. This is done for brevity and is not meant to imply a geological description.** For completeness, the core photographs are also provided below along with the reference numbers. Additional photographs were taken when test specimens were created from each sample and these are provided in the Test Results section of the report.

2.2.1. Oil Sands

Table 1 Summary of full diameter frozen oil sand core samples. Core plugs to be obtained for testing of selected cores as indicated.

Sample ID	Core Interval Top Depth (mKB)	Length (cm)	Lithology	Sample for Testing	Description
Well ID: Paramount Leismer 09-28-78-10W4M					
SC19	420.20	20	oil sand		Fine grained uniform oil sand with possible vertical fractures, extent of fractures into the core unknown
SC20	420.65	25	oil sand		Fine grained uniform oil sand with possible vertical fractures, extent of fractures into the core unknown
SC21	420.90	25	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC22	421.15	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC23	422.10	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC24	422.30	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC25	422.50	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC26	422.90	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC27	426.00	24	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample
SC28	426.56	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC29	426.76	20	oil sand		Fine grained uniform oil sand without any visible fractures, good sample
SC30	427.30	20	oil sand	√	Fine grained uniform oil sand without any visible fractures, good sample

Figure 2. Oil Sands Sample SC19 (from Paramount Leismer 09-28-78-10W4M)

Figure 3. Oil Sands Sample SC21 (from Paramount Leismer 09-28-78-10W4M)

Figure 4. Oil Sands Sample SC22 (from Paramount Leismer 09-28-78-10W4M)

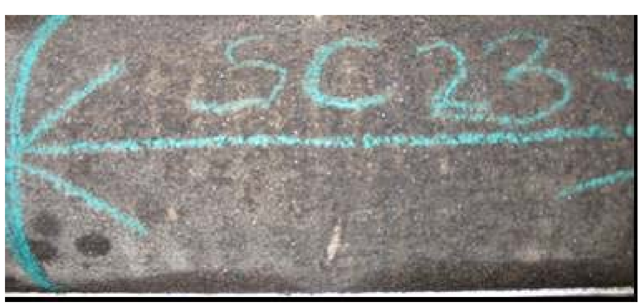


Figure 5. Oil Sands Sample SC23 (from Paramount Leismer 09-28-78-10W4M)

Figure 6. Oil Sands Sample SC24 (from Paramount Leismer 09-28-78-10W4M)

Figure 7. Oil Sands Sample SC25 (from Paramount Leismer 09-28-78-10W4M)

Figure 8. Oil Sands Sample SC26 (from Paramount Leismer 09-28-78-10W4M)

Figure 9. Oil Sands Sample SC27 (from Paramount Leismer 09-28-78-10W4M)

Figure 10. Oil Sands Sample SC28 (from Paramount Leismer 09-28-78-10W4M)

Figure 11. Oil Sands Sample SC29 (from Paramount Leismer 09-28-78-10W4M)

Figure 12. Oil Sands Sample SC30 (from Paramount Leismer 09-28-78-10W4M)

2.2.2. Shale Samples

Table 2 Summary of full diameter unfrozen oil sand and shale core samples preserved in wax. Core plugs to be obtained for testing of selected cores as indicated.

Sample ID	Core Interval Top Depth (mKB)	Length (cm)	Lithology	Samples for Testing	Description
Well ID: Paramount Leismer 09-28-78-10W4M					
SC1	387.89	21	Inter-laminated sand and mudstone		Finely interlaminated sand and mudstone with light cementation and no visible natural fractures
SC2	388.10	17	Inter-laminated sand and mudstone		Finely interlaminated sand and mudstone with light cementation and no visible natural fractures
SC3	394.56	15	silty mudstone	√	Weakly laminated silty mudstone without fissility or fractures
SC4	394.71	20	silty mudstone	√	Weakly laminated silty mudstone without fissility or fractures
SC5	397.50	15	silty mudstone	√	Weakly cemented mudstone with inter-laminated silts without visible natural fractures
SC6	397.65	20	silty mudstone	√	Weakly cemented mudstone with inter-laminated silts without visible natural fractures
Well ID: Paramount Leismer 03-03-79-10W4M					
SC7	406.22	17	shale		Very fissile shale with numerous bedding-parallel hairline cracks
SC8	406.39	12	shale		Very fissile shale with numerous bedding-parallel hairline cracks
SC9	406.51	9	shale		Very fissile shale with numerous bedding-parallel hairline cracks
SC10	406.95	10	shale		Fissile shale without fractures
SC11	407.27	19	shale		Fissile shale without fractures
SC12	407.46	22	siltstone		Cemented siltstone
SC13	411.45	20	Laminated oil sand		Extremely weak oil sand with shale laminations
SC14	411.65	20	Laminated oil sand		Extremely weak oil sand with shale laminations
SC15	411.85	20	Laminated oil sand		Extremely weak oil sand with shale laminations
SC16	412.05	12	Laminated oil sand		Extremely weak oil sand with shale laminations
SC17	413.05	20	Inter-laminated shale and oil sand		Interlaminated shale and oil sand without visible fractures
SC18	413.25	20	Inter-laminated shale and oil sand		Inter-laminated shale and oil sand without visible fractures

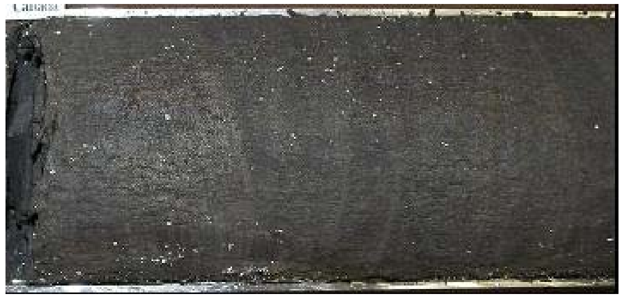


Figure 13. Interbedded mudstone/oil sands Sample SC1 (from Paramount Leismer 09-28-78-10W4M)

Figure 14. Interbedded mudstone/oil sands Sample SC2 (from Paramount Leismer 09-28-78-10W4M)

Figure 15. Interbedded mudstone/oil sands Sample SC3 (from Paramount Leismer 09-28-78-10W4M)

Figure 16. Interbedded mudstone/oil sands Sample SC4 (from Paramount Leismer 09-28-78-10W4M)

Figure 17. Interbedded mudstone/oil sands Sample SC5 (from Paramount Leismer 09-28-78-10W4M)

Figure 18. Interbedded mudstone/oil sands Sample SC6 (from Paramount Leismer 09-28-78-10W4M)

Figure 19. Interbedded mudstone/oil sands Sample SC7 (from Paramount Leismer 03-03-79-10W4M)

Figure 20. Interbedded mudstone/oil sands Sample SC8 (from Paramount Leismer 03-03-79-10W4M)

Figure 21. Interbedded mudstone/oil sands Sample SC9 (from Paramount Leismer 03-03-79-10W4M)

Figure 22. Interbedded mudstone/oil sands Sample SC10 (from Paramount Leismer 03-03-79-10W4M)

Figure 23. Interbedded mudstone/oil sands Sample SC11 (from Paramount Leismer 03-03-79-10W4M)

Figure 24. Interbedded mudstone/oil sands Sample SC12 (from Paramount Leismer 03-03-79-10W4M)

Figure 25. Interbedded mudstone/oil sands Sample SC13 (from Paramount Leismer 03-03-79-10W4M)

Figure 26. Interbedded mudstone/oil sands Sample SC14 (from Paramount Leismer 03-03-79-10W4M)

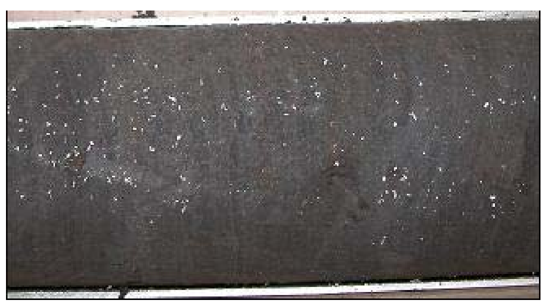


Figure 27. Interbedded mudstone/oil sands Sample SC15 (from Paramount Leismer 03-03-79-10W4M)

Figure 28. Interbedded mudstone/oil sands Sample SC16 (from Paramount Leismer 03-03-79-10W4M)

Figure 29. Interbedded mudstone/oil sands Sample SC17 (from Paramount Leismer 03-03-79-10W4M)

Figure 30. Interbedded mudstone/oil sands Sample SC18 (from Paramount Leismer 03-03-79-10W4M)

3. EXPERIMENTAL PROGRAM

3.1.1. Material Characterization Tests

For shale specimens, Atterberg limits, particle size distribution and grain density measurements were conducted. For oil sands specimens, grain size distribution as well as Dean Stark extraction tests were conducted.

3.1.2. Porewater Salinity

In order to saturate all the test specimens for this program, it was necessary to create a porewater solution that matched the ionic strength of the in situ porewater. For this test program, a salinity of 3,000 ppm was chosen based on previous work conducted at the University of Alberta on porewater salinity with the Clearwater Formation clayshale.

3.1.3. Triaxial Tests

Oil Sands

For the oil sands testing program, five isotropically consolidated drained triaxial compression tests were conducted. At specific intervals during certain tests, permeability tests to measure absolute permeability (NTX1, 3, 4 & 5) and effective permeability to water (NTX2) were also conducted. All tests were conducted at ambient temperature (i.e. laboratory temperature of 21 ^{o}C). The test conditions for the oil sands tests are listed below in Table 3:

Table 3 Test conditions for oil sands testing

Test Code	Specimen Depth [m]	Initial Cyclic Compression Stress [MPa]	Pre-shear Effective Confining Stress [MPa]	Bitumen Extracted?
NTX1	420.90	0.05 – 4.95	2.44	Yes
NTX2	421.15	0.05 – 4.94	2.47	No
NTX3	422.50	0.05 – 2.90	0.49	Yes
NTX4	426.00	0.05 – 6.16	4.37	Yes
NTX5	427.30	0.05 – 8.83	8.11	Yes

Shale

For the shale testing program, five isotropically consolidated undrained triaxial compression tests with pore pressure measurement were conducted. At the conclusion of each test, permeability tests to measure the effective permeability to water were also conducted. All tests were conducted at ambient temperature (i.e. laboratory temperature of 21 ^{o}C). The test conditions for the shale tests were:

Table 4 Test conditions for shale specimens

Test Code	Specimen Depth [m]	Initial Cyclic Compression Stress [MPa]	Pre-shear Effective Confining Stress [MPa]
ST1	394.56	0.05 – 3.34	0.71
ST2	397.50	0.05 – 4.21	1.06
ST3	397.65	0.05 – 3.39	0.96

ST4	394.71	0.05 – 4.53	4.53
ST5	394.81	0.05 – 6.33	6.35
ST6	397.75	0.05 – 3.39	0.56

4. MATERIAL CHARACTERIZATION TESTS

4.1. Specific Gravity

Table 5 lists all the index properties of the samples on which strength tests were performed. In addition to specific gravity, initial properties of the samples are important as they may be representative of the in situ properties of the material. G_s varies between a range of 2.61 – 2.68 with an average value of 2.67. The similarity of G_s across the oil sands and shale specimens reflects the variable sand/silt/shale lithology characteristic of the shale specimens.

4.2. Moisture Content

Extraction tests conducted on the oil sands specimens showed that all the specimens chosen for testing contained bitumen saturation in excess of 85% of the pore volume. The initial water saturation ranged from 8.1% to 14.6%, with an average value of 11.2%.

The moisture contents of the shale specimens vary from 9.27% to 9.85% with an average of 9.5%. Note that this moisture content is the geotechnical definition of moisture content which is mass of water divide by mass of solids.

4.3. Void Ratio / Porosity

For the oil sands specimens, the average void ratio for all five specimens was 0.557 which corresponds to an initial porosity of 35.7%. Void ratio is defined as the volume of voids divided by the volume of solids and is related to porosity through the following equation:

$$\text{Porosity, } \phi = e/(1+e).$$

For shale samples, the void ratio ranges from 0.152 to 0.263 which corresponds to a range in porosities from 13.2% to 20.8%. Note that the porosity of specimen ST4 is very low and as will be seen subsequently, this is indicative of a cemented siltstone specimen and the results generated for this specimen are likely not representative of the shale interval.

4.4. Atterberg Limits

Another important set of properties that have direct correlation with shear strength and state of a clayey soil as they exist in their in situ state is Atterberg Limits. The Atterberg limits refer to the consistency limits which are the moisture content values defining a boundary between two states of the material. For example, liquid limit (LL) is a value of moisture content forming the boundary between the liquid and plastic state of the material. Table 5 shows the value of liquid and plastic limits of each shale sample tested for strength properties. The values of plasticity index of the material are also listed.

Table 5 Summary of index property tests on oil sands and shale specimens.

Oil Sands

Test #	Core #	G_s	Bulk Mass			e_o	ϕ_{omeas}	Pore Volume	
			Bit%	Sand%	Water%			Bit	Water
NTX1	SC21	2.67	15.84	82.65	1.51	0.561	35.9%	0.913	0.087
NTX2	SC22	2.67	15.39	82.46	2.15	0.568	36.2%	0.877	0.123
NTX3	SC25	2.67	15.16	83.51	1.33	0.527	34.5%	0.919	0.081
NTX4	SC27	2.68	14.51	83.00	2.49	0.549	35.4%	0.854	0.146
NTX5	SC30	2.68	16.52	81.21	2.27	0.580	36.7%	0.879	0.121

Shale

Test #	Core #	G_s	W_L%	Wp%	Ip%	S%	w%	e_o	ϕ_o
ST1	SC3	2.68	25.8	15.7	10.1	-*	-*	0.260	20.6%
ST2	SC5	2.67	29.8	16.0	13.8	91.0	9.85	0.263	20.8%
ST3	SC6	2.61	32.4	15.2	17.3	91.1	9.79	0.256	20.4%
ST4	SC4	2.67	nil	nil	nil	91.5	9.27	0.152	13.2%
ST5	SC4	2.67	nil	nil	nil	91.5	9.27	0.260	20.6%
ST6[1]	SC6	2.61	32.4	15.2	17.3	91.1	9.79	0.256	20.4%

* tests were not conducted

[1] assumed to have same properties as ST3

where: G_s = specific gravity ; W_L = liquid limit ; W_P = plastic limit ; S = solids content (by mass) ; I_p = plasticity index ; w = initial moisture content ; e_o = initial void ratio ; ϕ_o = initial porosity

4.5. Particle Size Distribution (PSD)

Figure 31 shows the PSD for oil sands specimens. The particle size distribution gives an idea about the composition of soil based on average size of various constituent particles. Particle size distribution is a convenient way of categorizing the material on the basis of the constituent particle sizes. These oil sands specimens contain very little fines, only approximately 1 – 2% less than 2 μm. Figure 32 illustrates the PSD for the shale specimens. The variable lithology present in these samples is clearly evident in the grain size distributions for each of the specimens. On average, the shale specimens contain 10-15% clay sized materials with the exception of specimen ST4/ST5. This specimen has a low clay fraction (~ 2%) and this is reflected in the initial porosity of the specimen, 13.2%.

Based on the Atterberg limits the further classification of the soil as per Unified Soil Classification System (USCS) is shown in Figure 33. Specimens ST1, ST2, ST3 and ST6 can be generally categorized as inorganic clay of low plasticity (CL). Specimens ST4 and ST5 except no plastic characteristics.

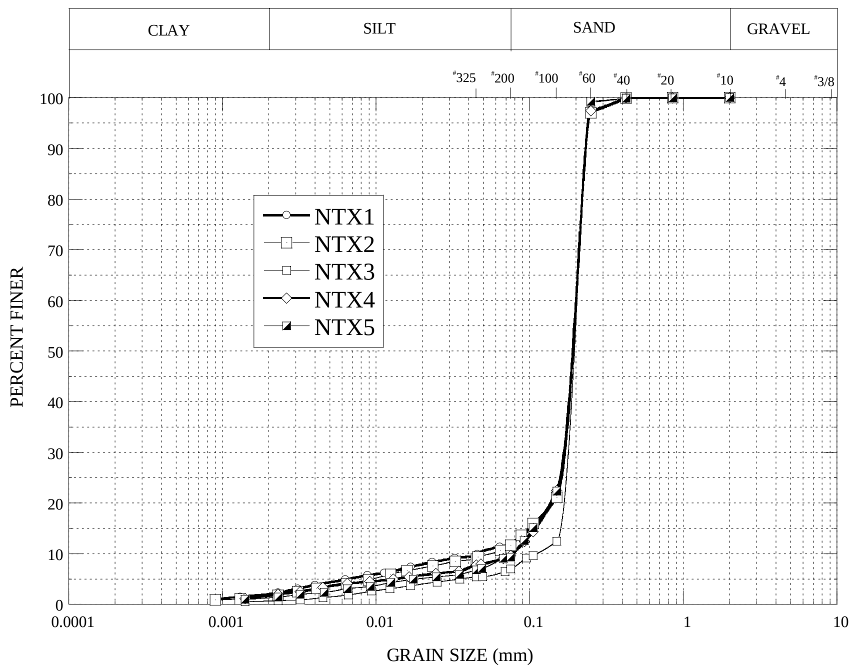


Figure 31. Particle size distributions for oil sands specimens

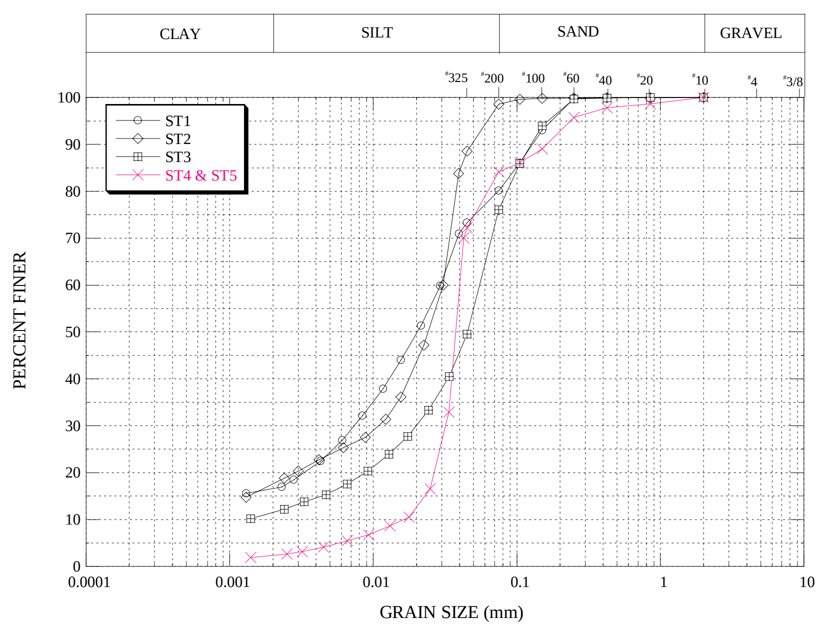


Figure 32. Particle size distributions for shale specimens

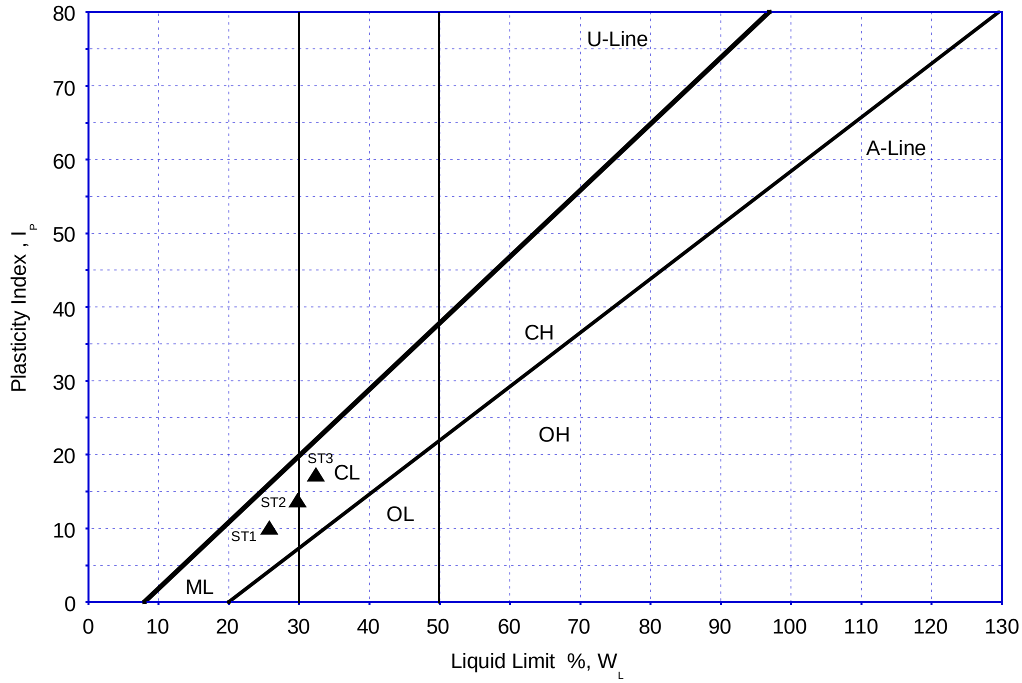


Figure 33. Plasticity chart used for soil classification of shale specimens

5. TEST RESULTS

5.1. Oil Sands Triaxial Tests

5.1.1. General Test Procedure

All oil sands specimens were prepared in a cold using a lathe to turn the sample to final specimen dimensions. All oil sands specimens were trimmed to a nominal 63.5 mm diameter and 127.0 mm length. Exact specimen dimensions are recorded in each test data file. After the trimming of the oil sands specimen in the lath machine, the specimen dimensions and weight are recorded. The frozen specimen is placed between two sintered brass porous plates in a bitumen flushing apparatus. A neoprene membrane is installed around the specimen and endcaps. The apparatus is filled with water and 50kPa confining pressure is applied. The frozen specimen will be left inside the apparatus to thaw for overnight. Following thaw, the confining pressure is increased to about 250kPa, and a toluene pressure up to 200kPa is used to flush the bitumen from the specimen. The flushing process is continued until the outlet toluene fluid becomes clear. Water is subsequently injected through the specimen to flush excess toluene and to saturate the specimen. The water saturated sample is re-frozen by dry ice and transferred to the high pressure triaxial test cell, and ready for testing. If bitumen flushing is not required, then the lathed, frozen specimen is placed directly in the triaxial cell.

To minimize specimen disturbance post-bitumen flushing, a small suction pressure (~ 10 kPa) is applied to the specimen following water injection. Once the suction pressure is established, all fluid pressure valves are closed, locking the suction pressure within the specimen. The confining fluid is emptied from the cell and the specimen is frozen using dry ice. Once the specimen is placed in the triaxial cell, the specimen is allowed to thaw and saturate at a high back (pore) pressure, approximately 1.0 MPa, with an effective confining stress of 50kPa as seating load. Monitoring the flow rate and volume of the ISCO syringe pump for pore pressure measurement for steady state conditions (zero flow rates and volume change), the specimen saturation condition is assumed to have been achieved. An initial cyclic compression test over a range of effective confining stress levels is conducted at this stage. The final stage of the cyclic compression test is to allow the specimen to fully consolidate at the desired effective confining stress for the shear test.

After moving the loading ram in contact with the specimen, the system is allowed to stabilize for 20 to 30 minutes. The drained triaxial compression test is started by setting the axial strain rate at 0.07% of specimen height. The axial load and pore pressure are recorded and monitored until a residual axial stress condition is reached with constant pore pressure (drained conditions).

For the permeability testing stages, axial straining is stopped and the load ram is locked in place. A by-pass valve across the specimen is closed. A Quizix QL-700 paired cylinder pump is utilized to set prescribed flow rates across the specimen with top and bottom pressure measurements. The permeability flow is in the upward direction with constant flow rate delivery. Steady state permeability is reached when a constant pressure of the Quizix pump is measured. The permeant in all cases is saline porewater.

5.1.2. Bitumen Extraction Process

Figure 34 illustrates the test setup for bitumen flushing and the visual inspection procedure used to determine the progress and completion of the bitumen extraction process.

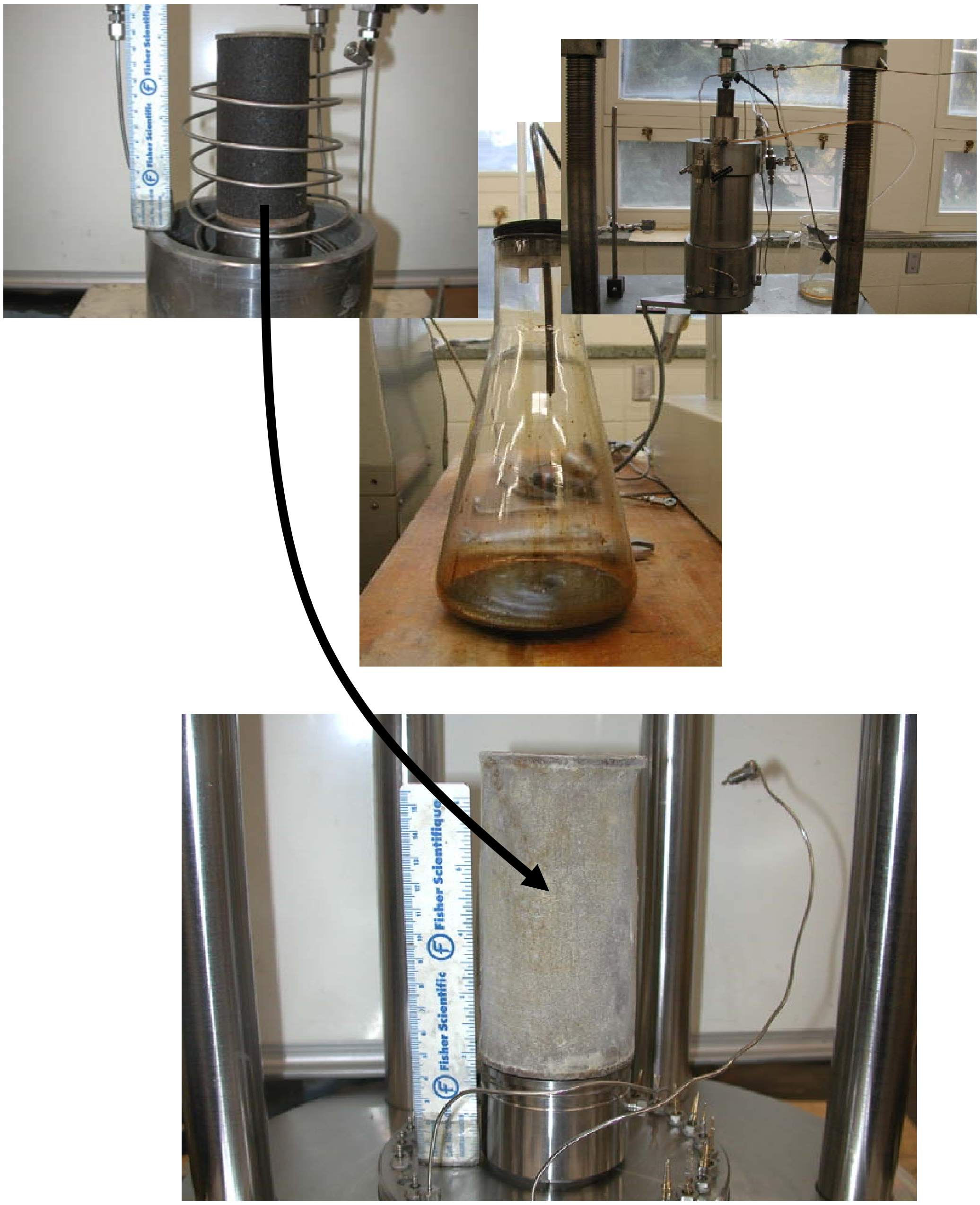


Figure 34. Demonstration of bitumen flushing efficiency for triaxial specimens

Regarding nomenclature, the following definitions for p' and q has been used in presenting all triaxial test results:

$$p' = (\sigma_1' + 2\sigma_3')/3$$

$$q = (\sigma_1' - \sigma_3')$$

5.1.3. Test NTX1: p_o' = 2.44 MPa

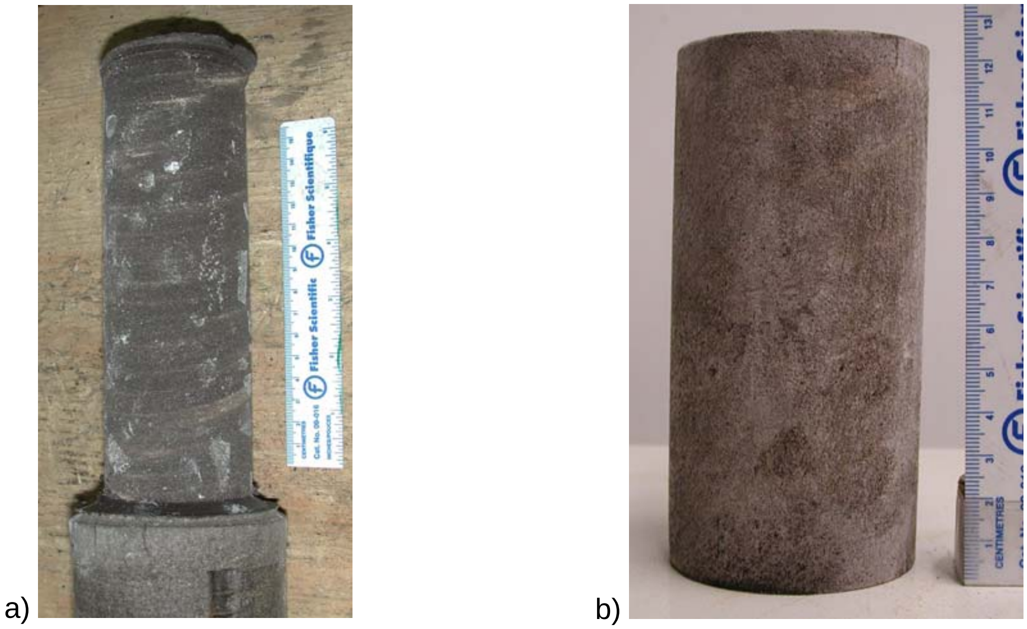


Figure 35. NTX1 test specimen a) frozen, lathed specimen b) final trimmed frozen bitumen saturated specimen

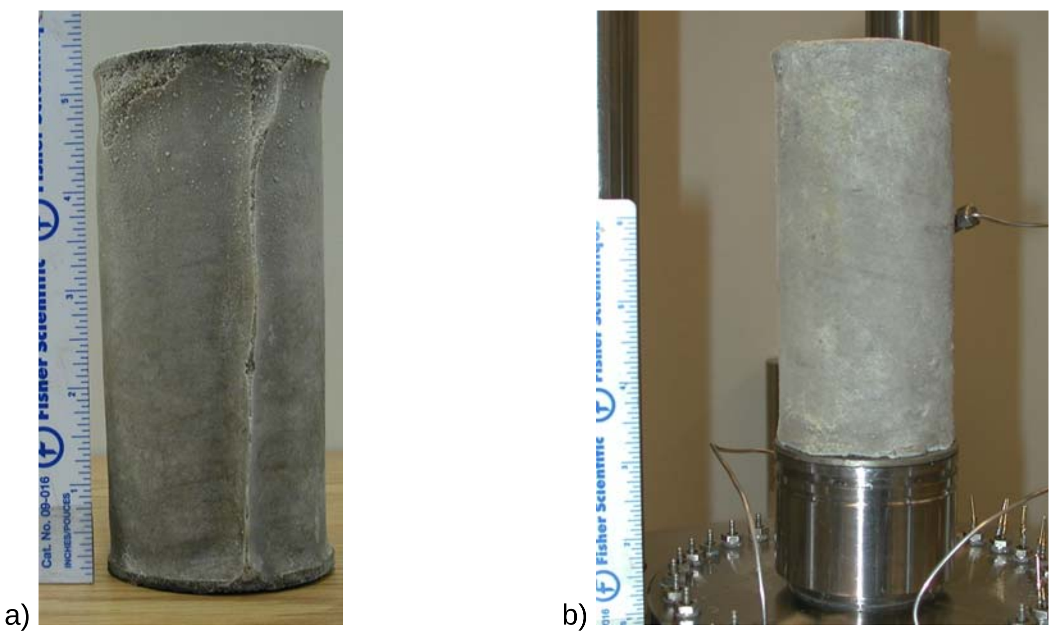


Figure 36. NTX1 test specimen a) frozen extracted specimen b) frozen bitumen free specimen installed in triaxial cell

a) 

b) 

Figure 37. NTX1 test specimen a) post-test specimen still insides membrane b) frozen post-test specimen frozen and membrane removed showing highly deformed state of specimen

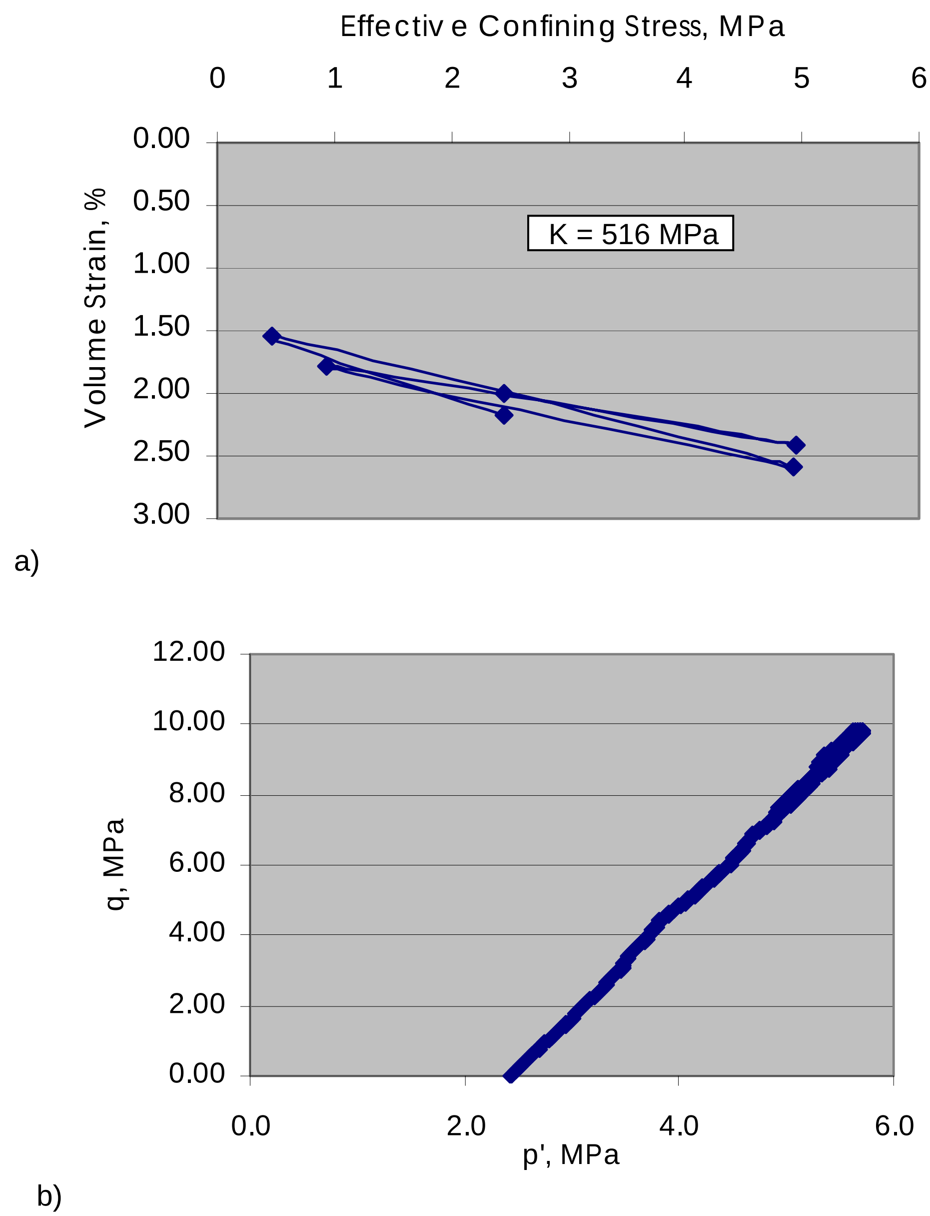


Figure 38. NTX1 triaxial test results a) compressibility b) stress path

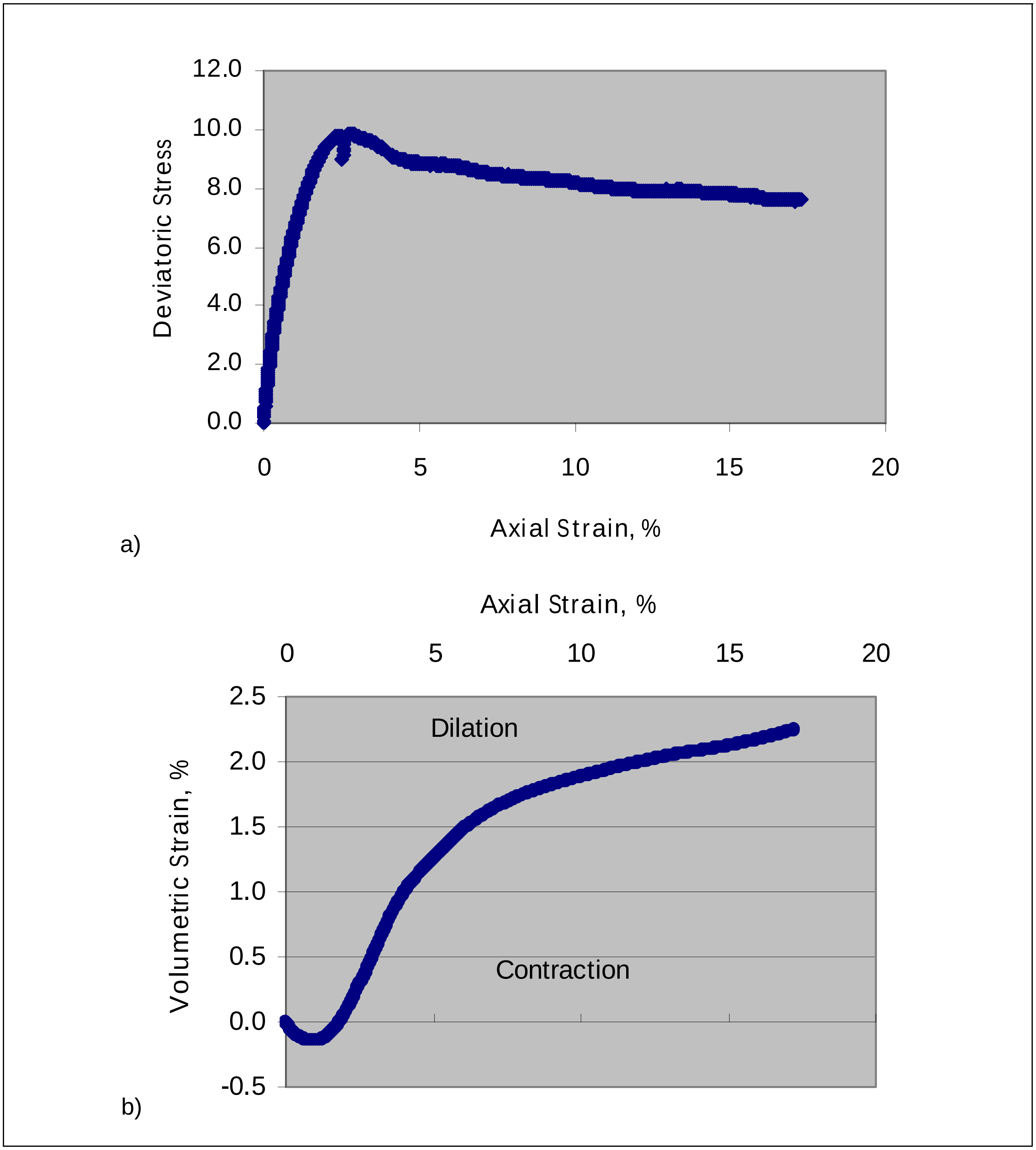


Figure 39. NTX1 triaxial test results a) stress-strain b) volume change

Table 6 Summary of permeability measurements on NTX1.

Permeability Calculation Test : NTX1

Sample: SC21

Initial Height, mm: **131.36** 13.136 cm
Area, mm^2: 0.002866000 28.66 cm^2

Permeability k= qL/hA

	Stage	Bottom Pressure MPa	Top Pressure MPa	Differential Pressure MPa	Ave.Flow Rate ml/min	Pressure Head, h cm	Flow Rate, q cm^3/s	X-Area cm^2	Sample Length, L cm	Permeability k cm/s	Permeability (mD)	
	Before Shear	1.01300	1.02364	0.01064	1.00	108.46	0.017	28.65	13.14	7.05E-05	73.3	
A	Before Shear	1.01300	1.03100	0.01800	2.00	183.55	0.033	28.65	13.14	8.33E-05	86.6	Average
	Before Shear	1.01300	1.04419	0.03119	4.00	318.06	0.067	28.65	13.14	9.62E-05	100.0	87
	Peak	1.01200	1.02141	0.00941	1.00	95.97	0.017	29.41	12.80	7.56E-05	78.6	
B	Peak	1.01200	1.02782	0.01582	2.00	161.36	0.033	29.41	12.80	8.99E-05	93.5	Average
	Peak	1.01200	1.04653	0.03453	4.00	352.09	0.067	29.41	12.80	8.24E-05	85.7	86
	After Shear	1.0140	1.0304	0.01643	1.00	167.53	0.017	34.62	10.88	3.78E-05	39.3	
C	After Shear	1.0140	1.0375	0.02352	2.00	239.87	0.033	34.62	10.88	5.27E-05	54.8	
	After Shear	1.0140	1.0506	0.03657	4.00	372.91	0.067	34.62	10.88	6.78E-05	70.6	Average
	After Shear	1.0140	1.0648	0.05076	6.00	517.62	0.100	34.62	10.88	7.33E-05	76.2	60

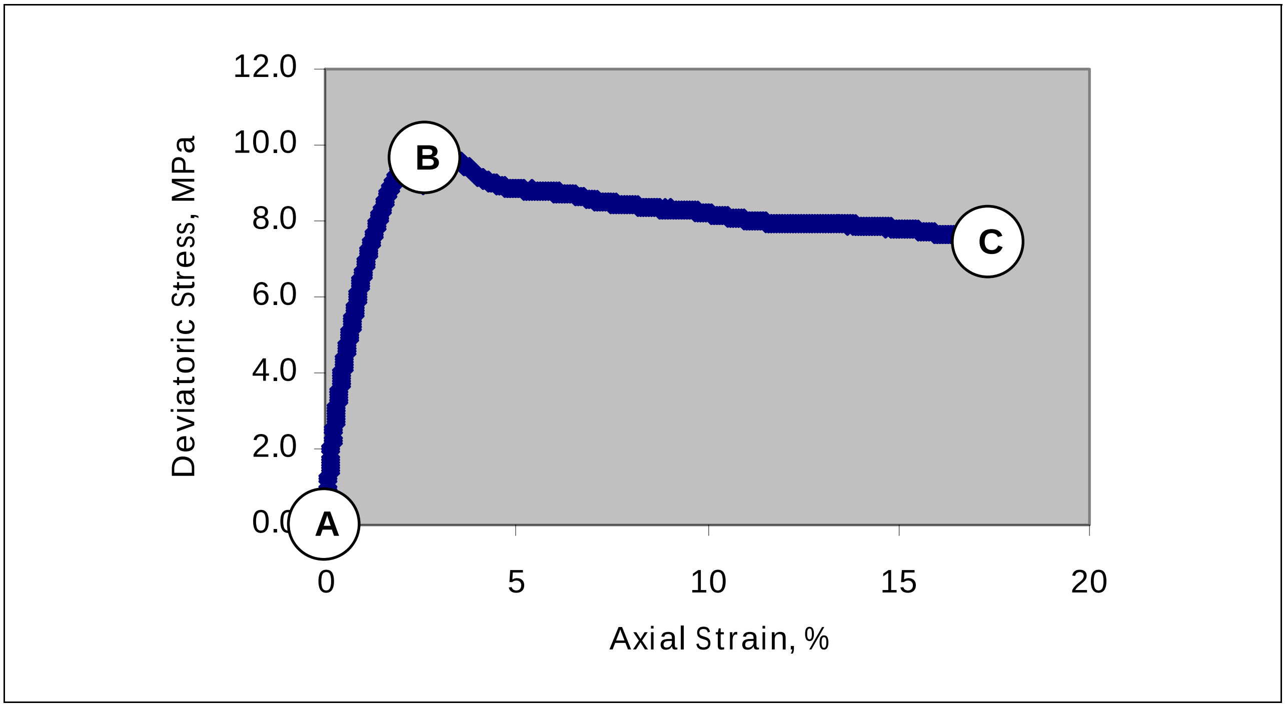


Figure 40. Locations in stress-strain curve where permeability measurements were taken on specimen NTX1

5.1.4. Test NTX2: p_o' = 2.47 MPa

a) 

b) 

Figure 41. NTX2 test specimen a) frozen, lathed specimen b) final trimmed frozen bitumen saturated specimen

a) 

b) 

Figure 42. NTX2 test specimen a) post-test specimen still insides membrane b) frozen post-test specimen frozen and membrane removed showing highly deformed state of specimen

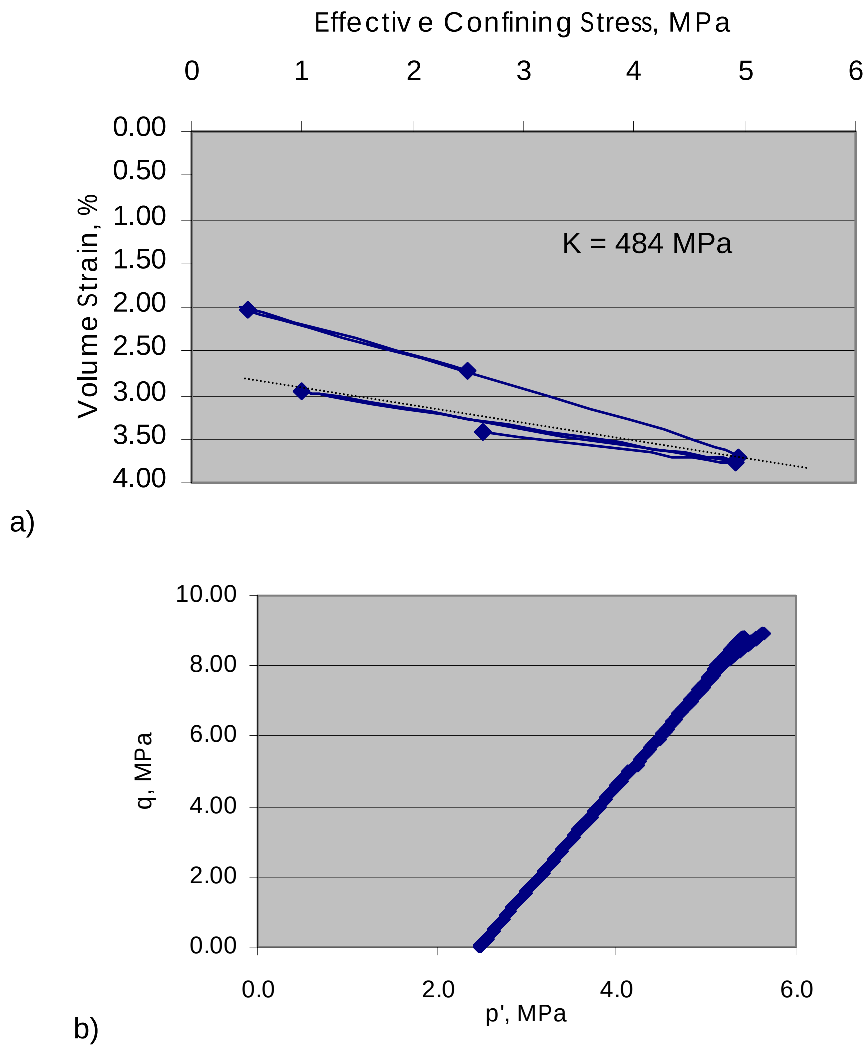


Figure 43. NTX2 triaxial test results a) compressibility b) stress path

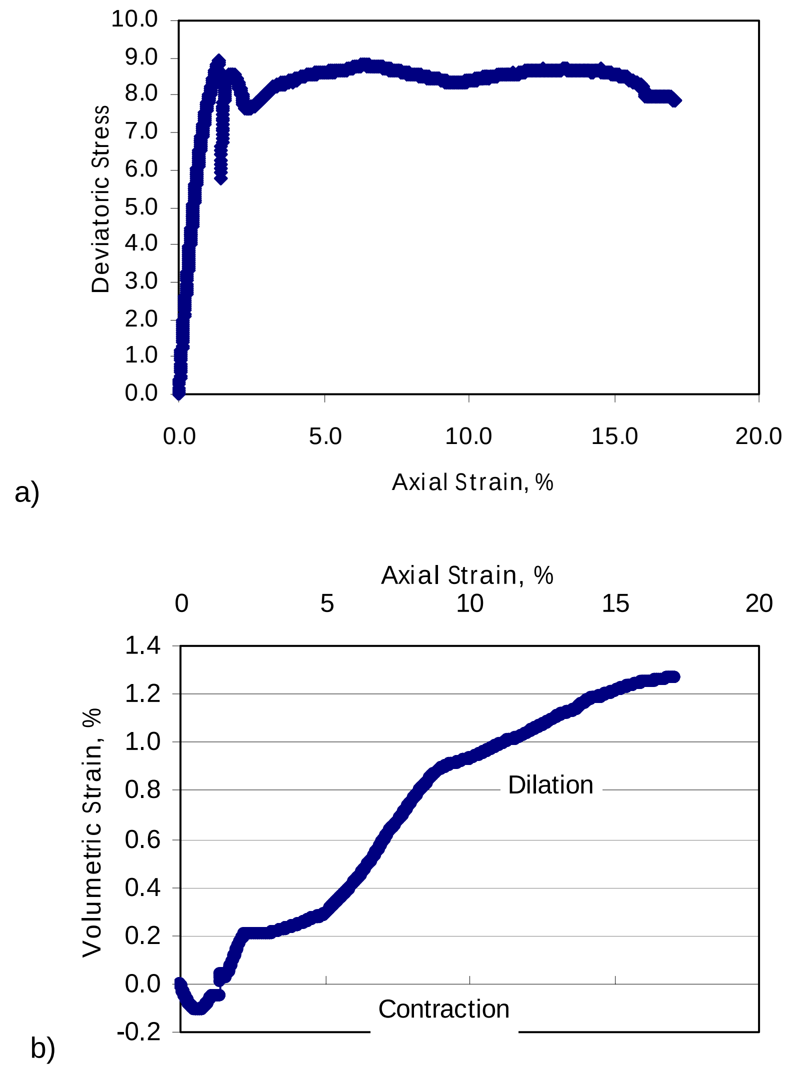


Figure 44. NTX2 triaxial test results a) stress-strain b) volume change

Table 7 Summary of permeability measurements on NTX2.

Permeability Calculation Test : NTX2

Sample: SC22

Initial Height, mm:	126.58	12.658	cm
Area, mm^2:	0.003074	30.74	cm^2

Permeabili k= qL/hA

	Stage	Initial Pressure MPa	Max Pressure MPa	Differential Pressure MPa	Ave.Flow Rate ml/min	Pressure Head, h cm	Flow Rate, q cm^3/s	X-Area cm^2	Sample Length, L cm	Permeability, k cm/s	Permeability, (mD)
A	Before Shear	0.9980	1.0183	0.0203	0.0020	207.3050	0.0000	30.7300	12.6602	6.6244E-08	0.0689
B	Peak	0.9950	2.1028	1.1078	0.0500	11296.0123	0.0008	31.1800	12.4806	2.9529E-08	0.0307
C	After Shear	1.0010	2.2459	1.2449	0.0750	12693.9904	0.0013	37.0900	10.4897	3.3602E-08	0.0349

Note: The low values of permeability shown in Table 7 reflect the low water saturation (high bitumen saturation) in the specimen – no bitumen was extracted from specimen NTX2.

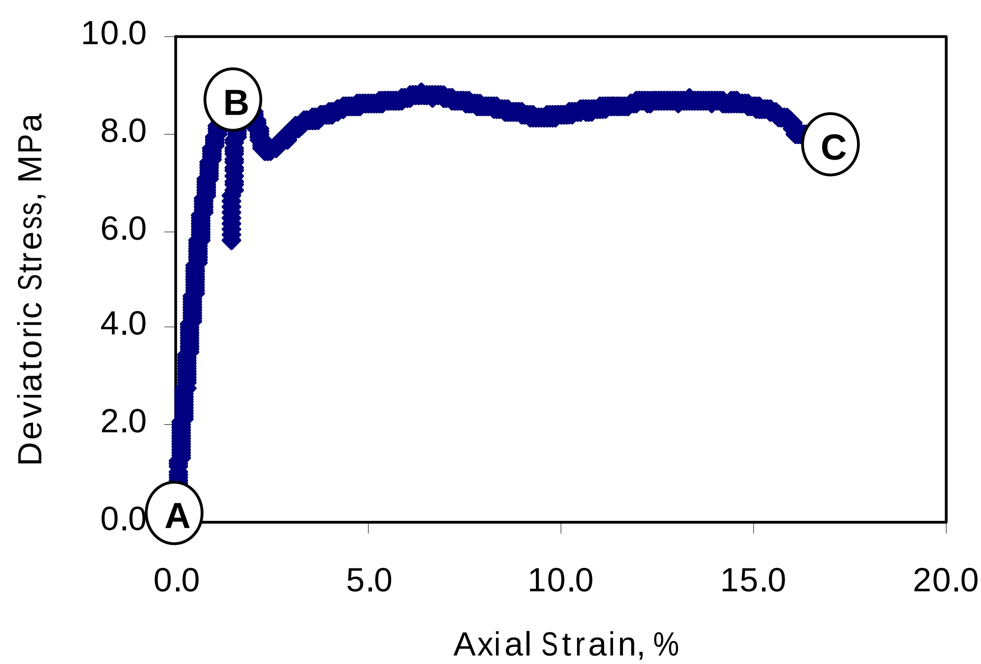


Figure 45. Locations in stress-strain curve where permeability measurements were taken on specimen NTX2

5.1.5. Test NTX3: $p_o' = 0.49$ MPa

a) no photo

b) 

Figure 46. NTX3 test specimen a) frozen, lathed specimen b) final trimmed frozen bitumen saturated specimen

a) 

b) no photo

Figure 47. NTX3 test specimen a) frozen extracted specimen b) frozen bitumen free specimen installed in triaxial cell

a) b)

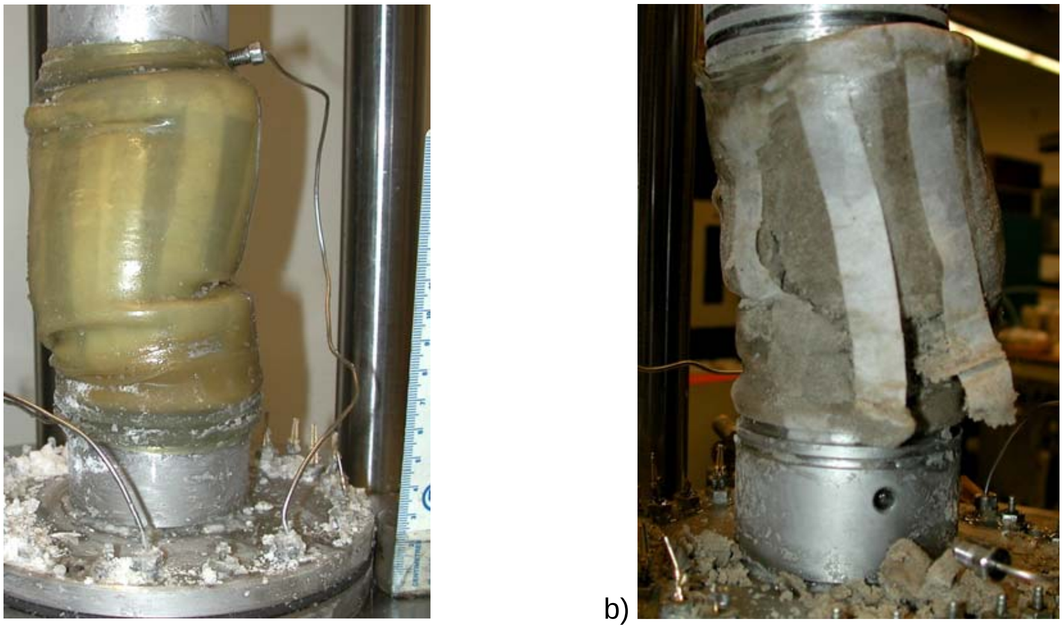


Figure 48. NTX3 test specimen a) post-test specimen still inside membrane b) frozen post-test specimen frozen and membrane removed showing highly deformed state of specimen

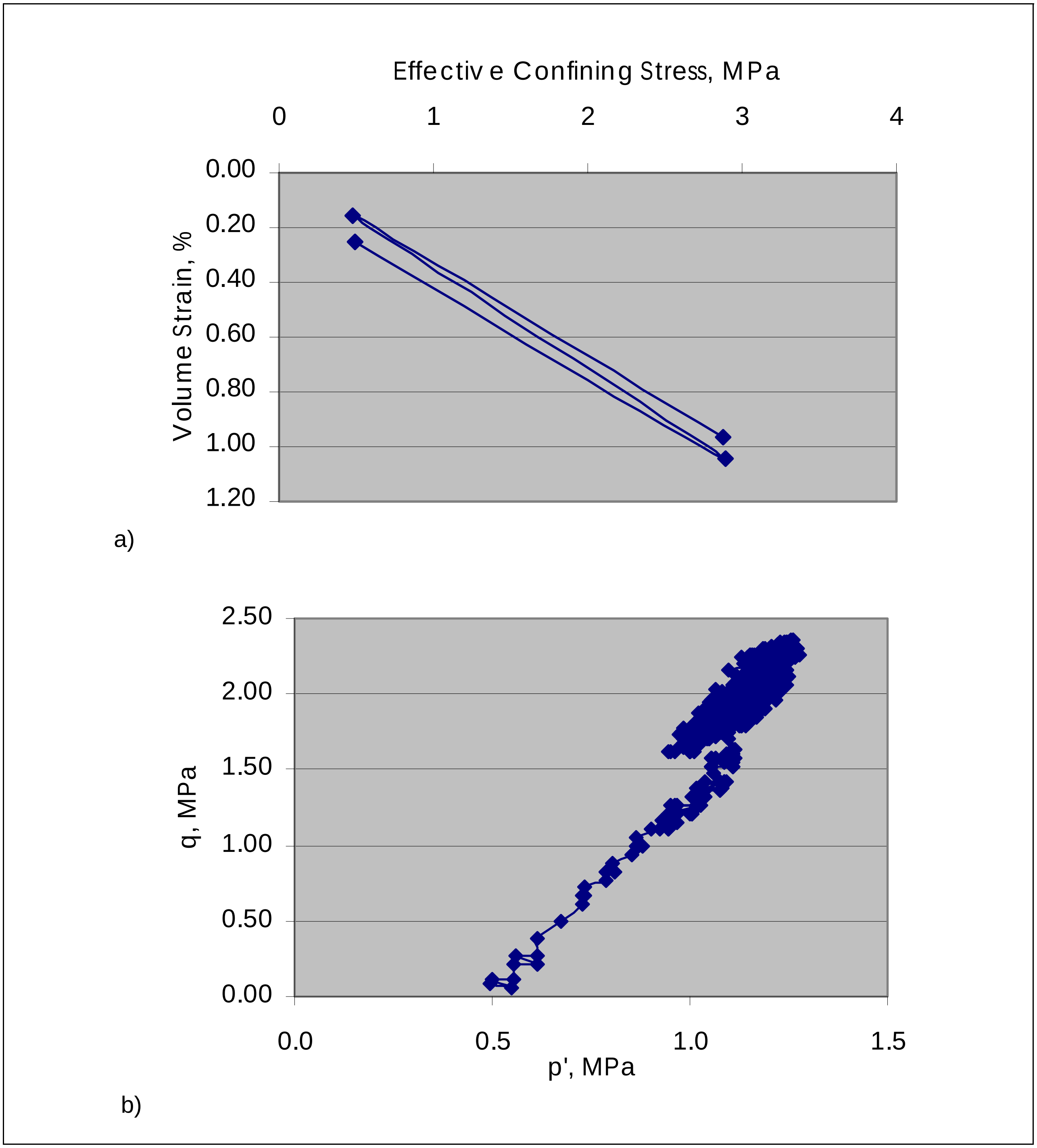
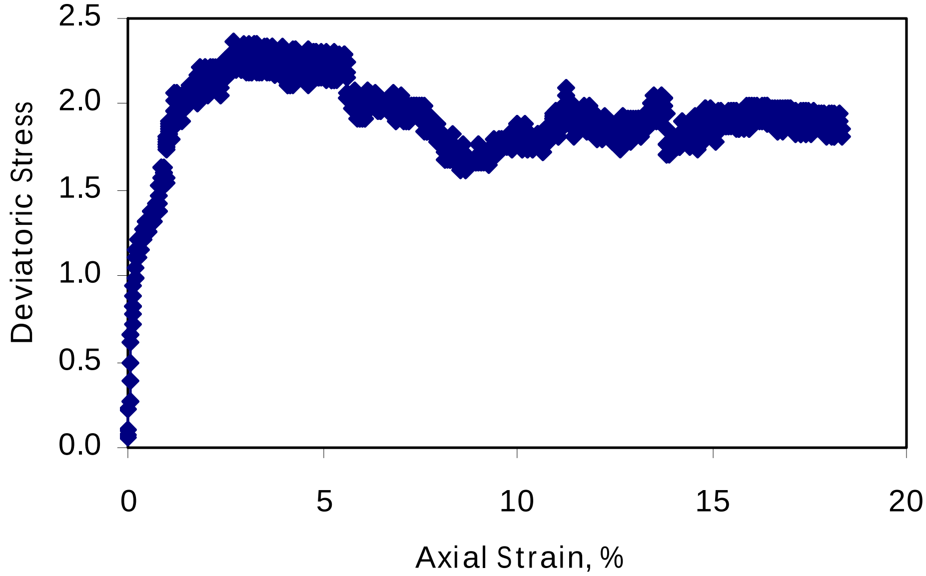
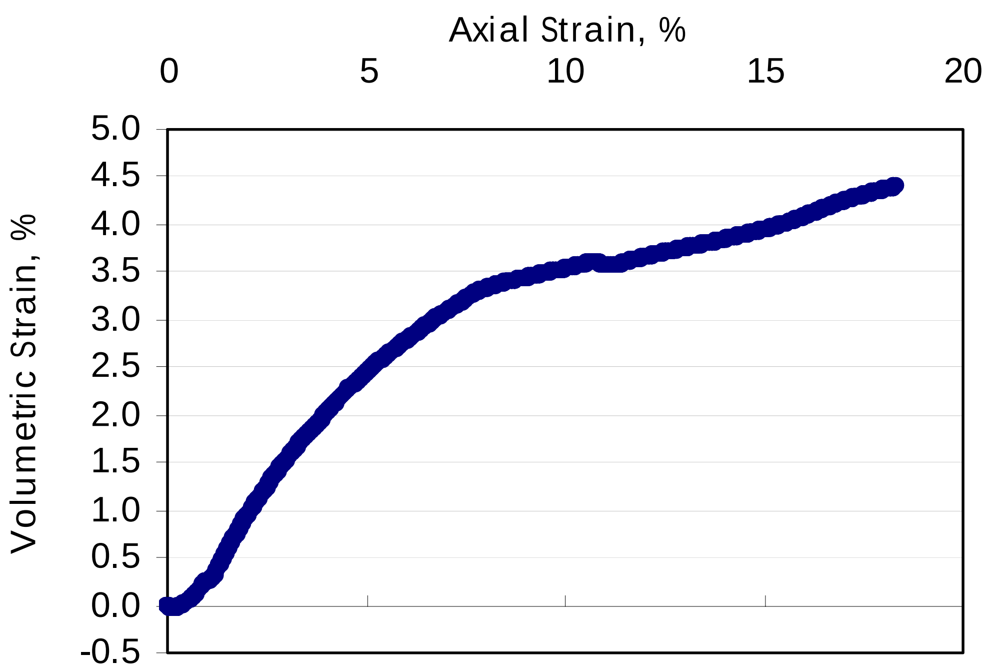


Figure 49. NTX3 triaxial test results a) compressibility b) stress path



a)



b)

Figure 50. NTX3 triaxial test results a) stress-strain b) volume change

Table 8 Summary of permeability measurements on NTX3.

Permeability Calculation Test : NTX3

Sample: SC25

Initial Height, mm: **125.91** 12.591 cm
Area, mm^2: 0.00298 29.8 cm^2

Permeability k= qL/hA

	Stage	Top Pressure MPa	Bottom Pressure MPa	Differential Pressure MPa	Ave.Flow Rate ml/min	Pressure Head, h cm	Flow Rate, q cm^3/s	X-Area cm^2	Sample Length, L cm	Permeability k cm/s	Permeability (mD)
A	Before Shear	0.9870	0.9977	0.01068	4.0	108.8734	0.066667	29.80	12.59	0.000258721	269
B	Peak	1.0000	1.0180	0.01800	4.0	183.546	0.066667	30.12	12.46	0.000150254	156
C	After Shear	1.0000	1.0288	0.0288	4.0	293.6736	0.066667	36.51	10.28	7.82878E-05	81

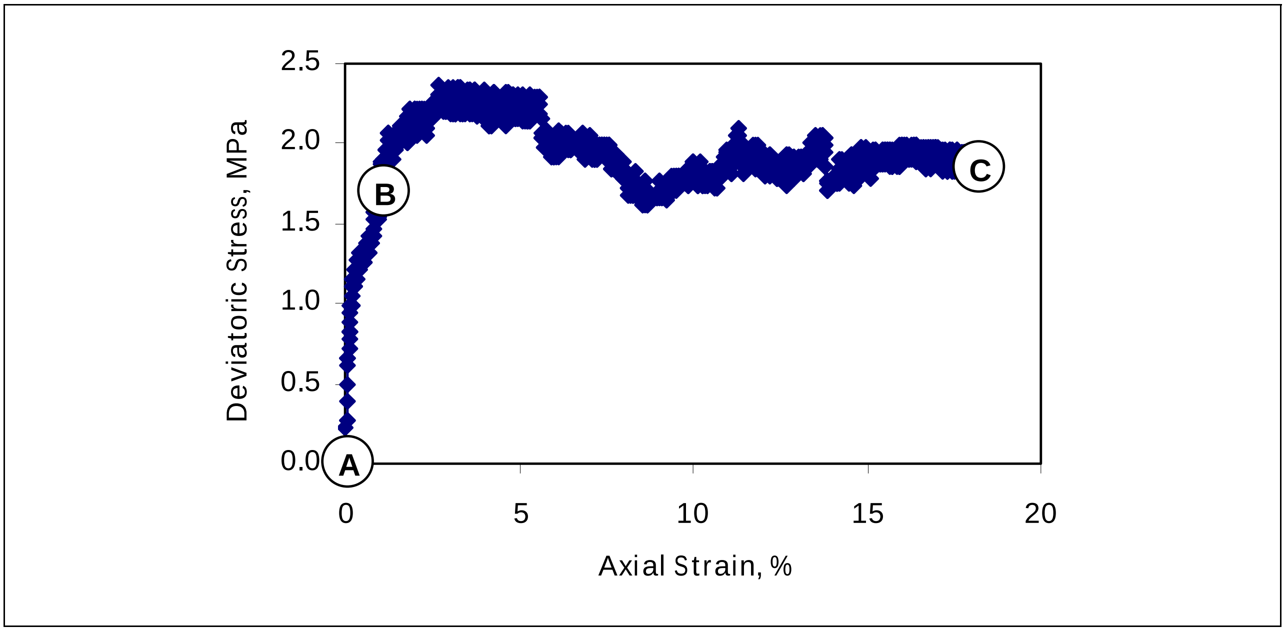


Figure 51. Locations in stress-strain curve where permeability measurements were taken on specimen NTX3

5.1.6. Test NTX4: p_o' = 4.37 MPa

a) no photo

b) 

Figure 52. NTX4 test specimen a) frozen, lathed specimen b) final trimmed frozen bitumen saturated specimen

a) no photo

b) 

Figure 53. NTX4 test specimen a) frozen extracted specimen b) frozen bitumen free specimen installed in triaxial cell

a) 

b) 

Figure 54. NTX4 test specimen a) post-test specimen still insides membrane b) frozen post-test specimen frozen and membrane removed showing highly deformed state of specimen

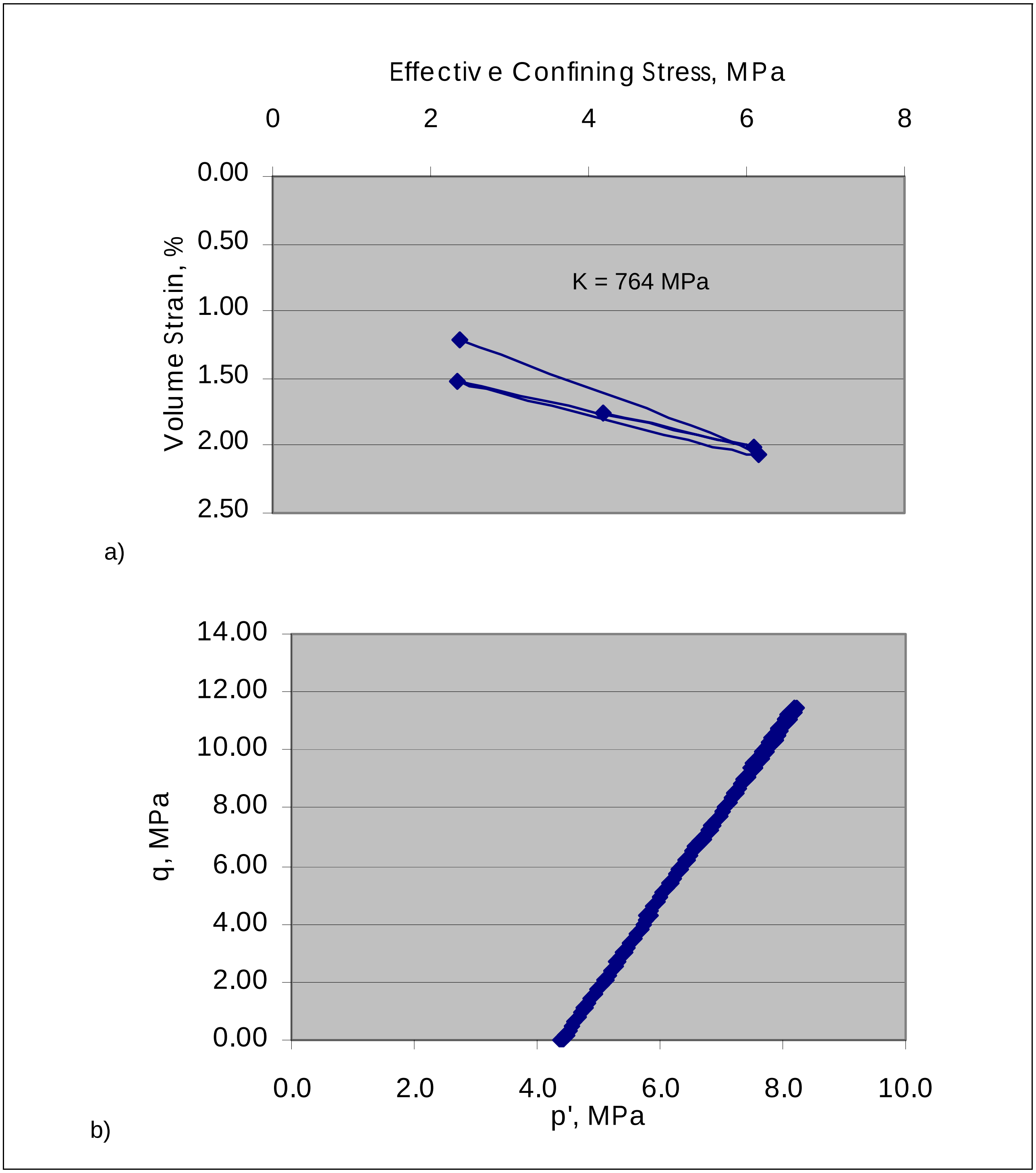


Figure 55. NTX4 triaxial test results a) compressibility b) stress path

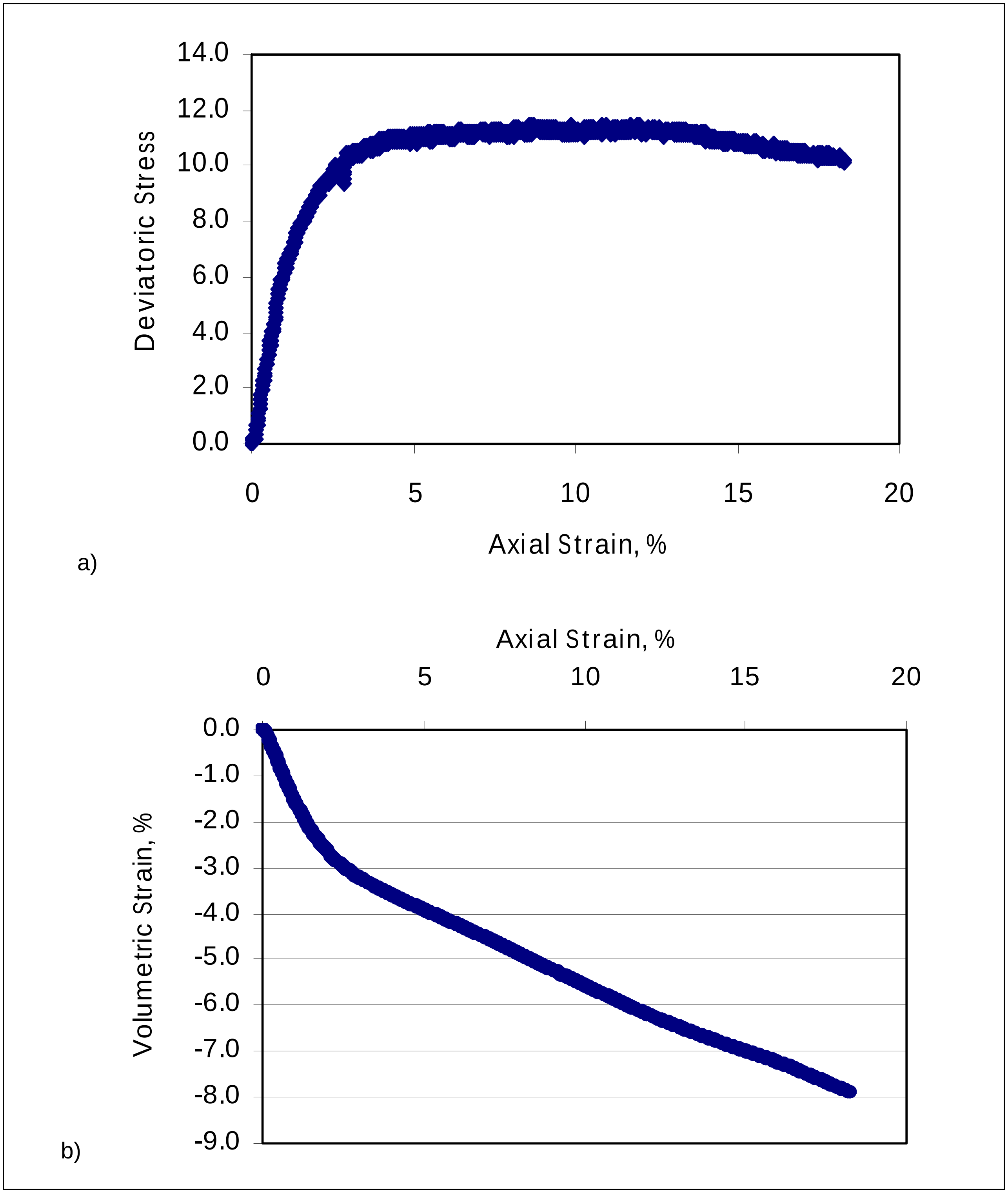


Figure 56. NTX4 triaxial test results a) stress-strain b) volume change

Table 9 Summary of permeability measurements on NTX4.

Permeability Calculation Test : NTX4

Sample: SC27

Initial Height, mm:	**126.05**	12.605	cm
Area, mm^2:	0.003043	30.43	cm^2

Permeability k= qL/hA

	Stage	Initial Pressure MPa	Max Pressure MPa	Differential Pressure MPa	Ave.Flow Rate ml/min	Pressure Head, h cm	Flow Rate, q cm^3/s	X-Area cm^2	Sample Length, L cm	Permeability k cm/s	Permeability mD
A	Before Shear	1.0240	1.05922	0.035222	4.0	359.1587	0.066667	30.83	12.442	7.49099E-05	78
B	Peak	1.0260	1.05784	0.03184	4.0	324.6725	0.066667	31.51	12.176	7.93437E-05	83
C	After Shear	1.0230	1.08467	0.061667	4.0	628.8184	0.066667	37.48	10.236	3.56639E-05	37

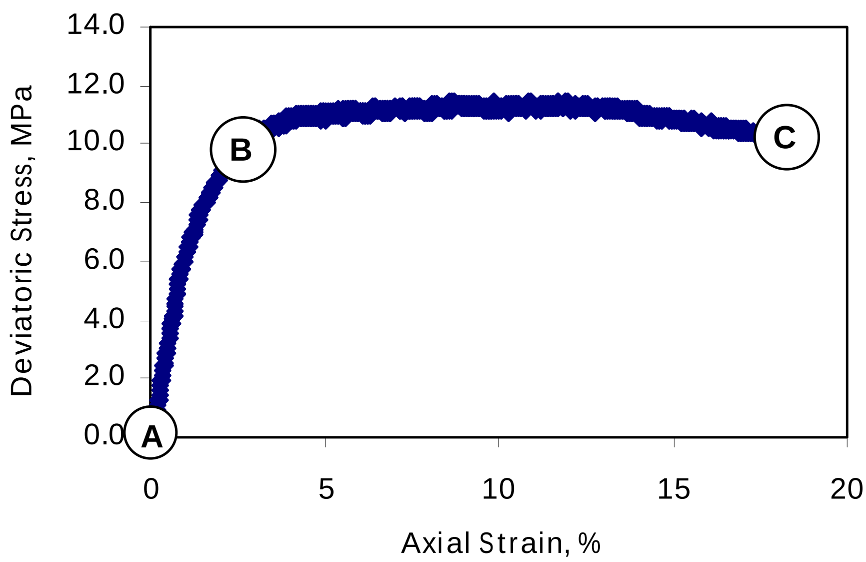


Figure 57. Locations in stress-strain curve where permeability measurements were taken on specimen NTX4

5.1.7. Test NTX5: p_o' = 8.11 MPa

a) no photo

b) 

Figure 58. NTX5 test specimen a) frozen, lathed specimen b) final trimmed frozen bitumen saturated specimen

a) 

b) no photo

Figure 59. NTX5 test specimen a) frozen extracted specimen b) frozen bitumen free specimen installed in triaxial cell

a) 

b) 

Figure 60. NTX5 test specimen a) post-test specimen still insides membrane b) frozen post-test specimen frozen and membrane removed showing highly deformed state of specimen

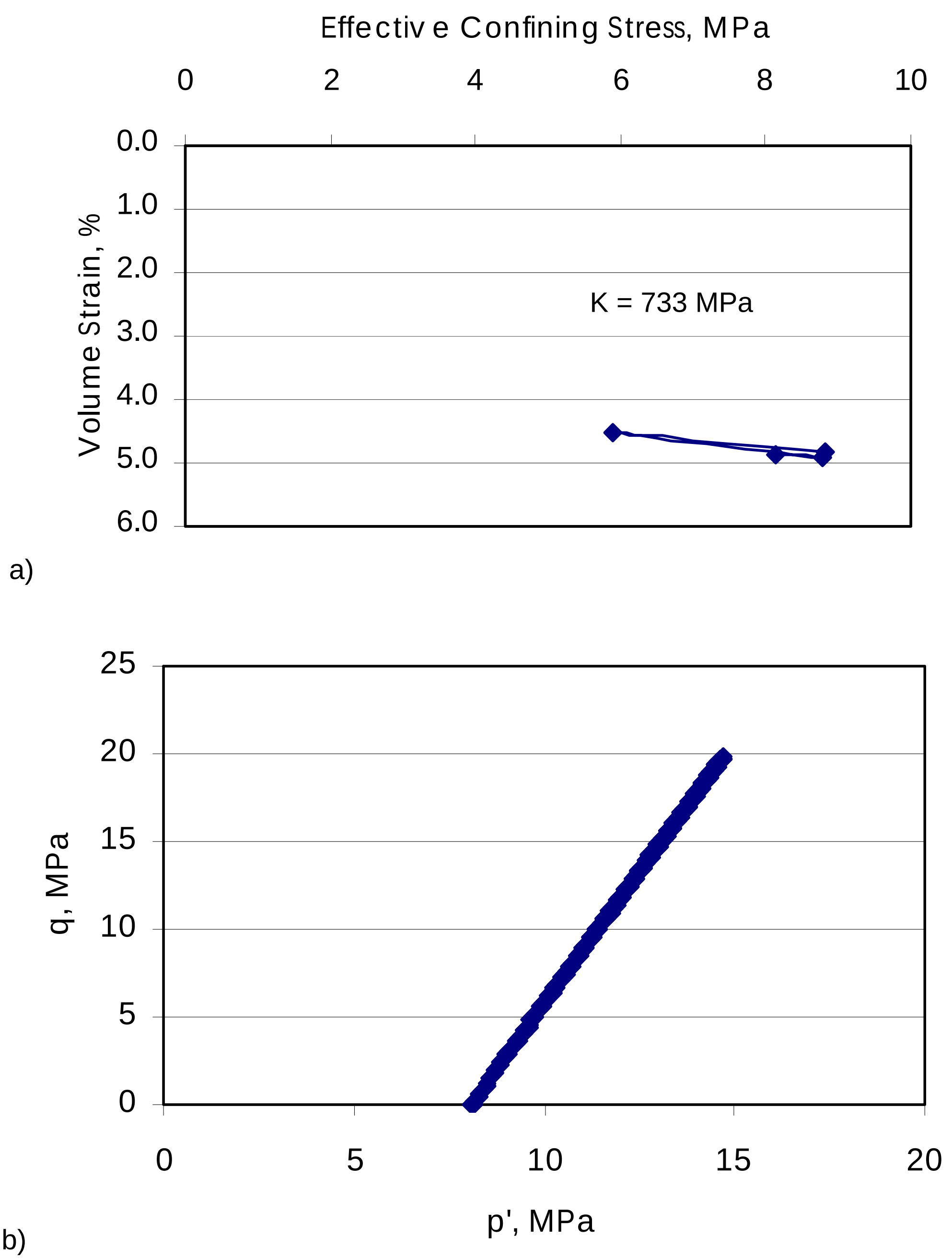


Figure 61. NTX5 triaxial test results a) compressibility b) stress path

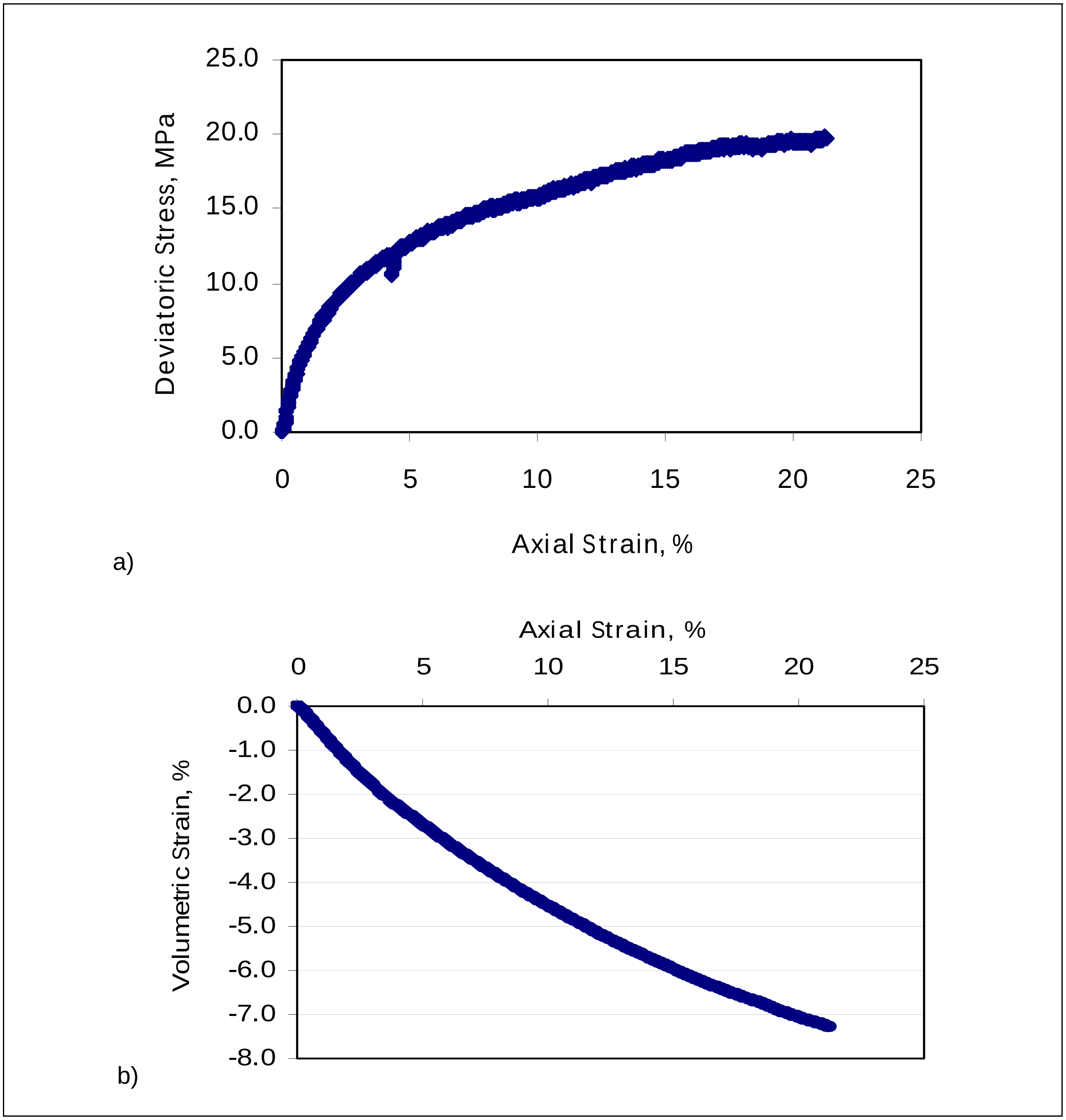


Figure 62. NTX5 triaxial test results a) stress-strain b) volume change

Table 10 Summary of permeability measurements on NTX5.

Permeability Calculation   Test : NTX5

Sample: SC30

Initial Height, mm: **128.05** 12.805 cm
Area, mm^2: 0.003028 30.28 cm^2

Permeability k= qL/hA

	Stage	Initial Pressure MPa	Max Pressure MPa	Differential Pressure MPa	Ave.Flow Rate ml/min	Pressure Head, h cm	Flow Rate, q cm^3/s	X-Area cm^2	Sample Length, L cm	Permeability k cm/s	Permeability mD
A	Before Shear	1.0080	1.01875	0.01075	4.0	109.6178	0.066667	30.78	12.5967	0.00024889	259
B	Post Peak	1.0020	1.021667	0.019667	4.0	200.5444	0.066667	32.17	12.0507	0.00012453	130
C	After Shear	1.0010	1.031765	0.030765	4.0	313.7107	0.066667	39.10	9.9151	6.9586E-05	72

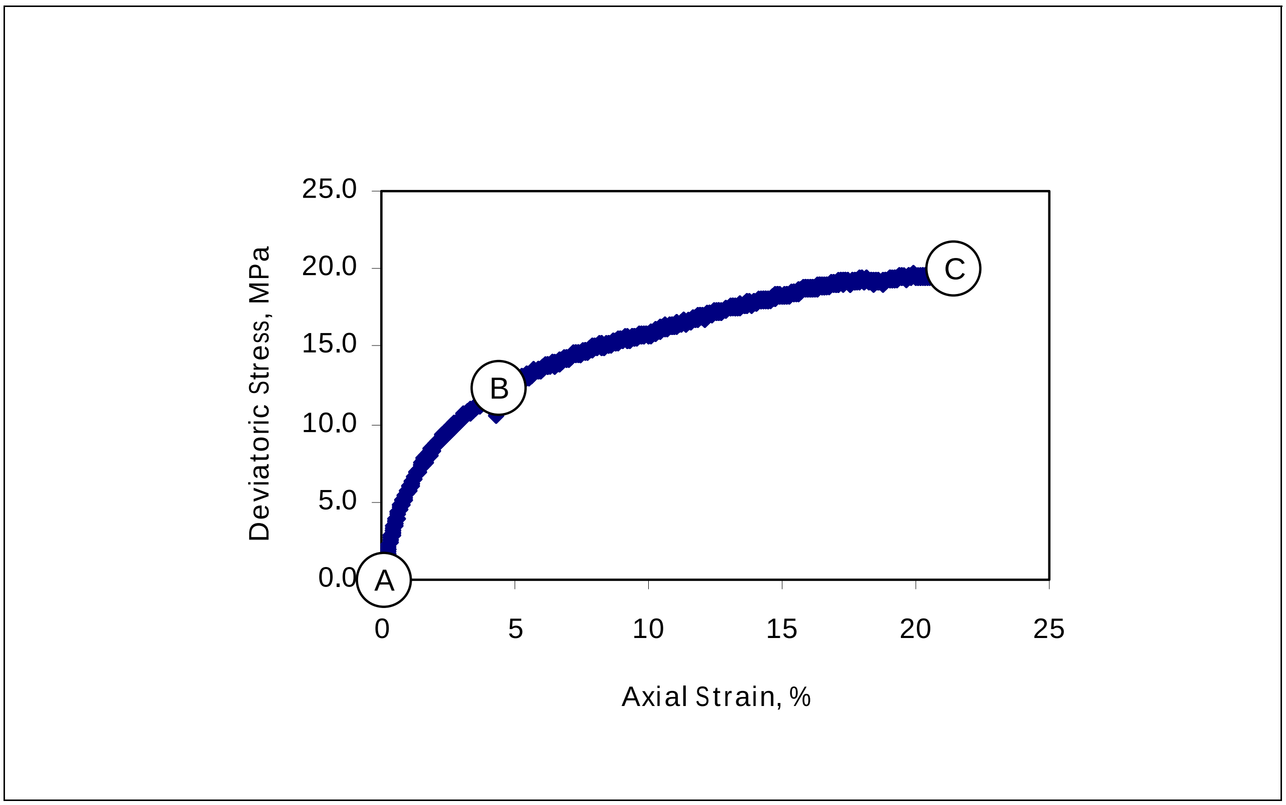


Figure 63. Locations in stress-strain curve where permeability measurements were taken on specimen NTX5

5.1.8. Summary of Triaxial Tests

Figures 64, 65, 66 and 67 provide summary plots of the triaxial tests completed on the oil sands specimens.

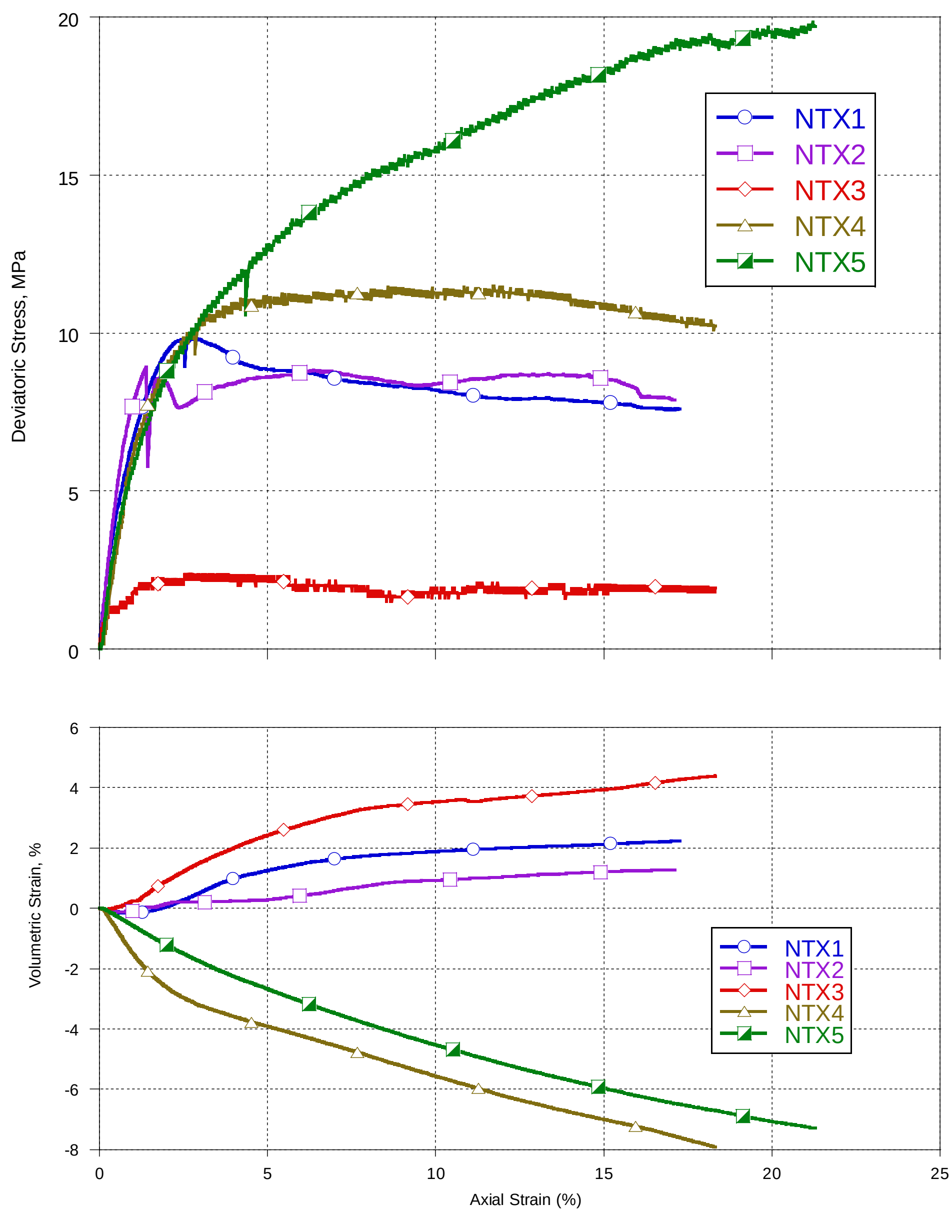


Figure 64. Summary of all oil sands triaxial test results

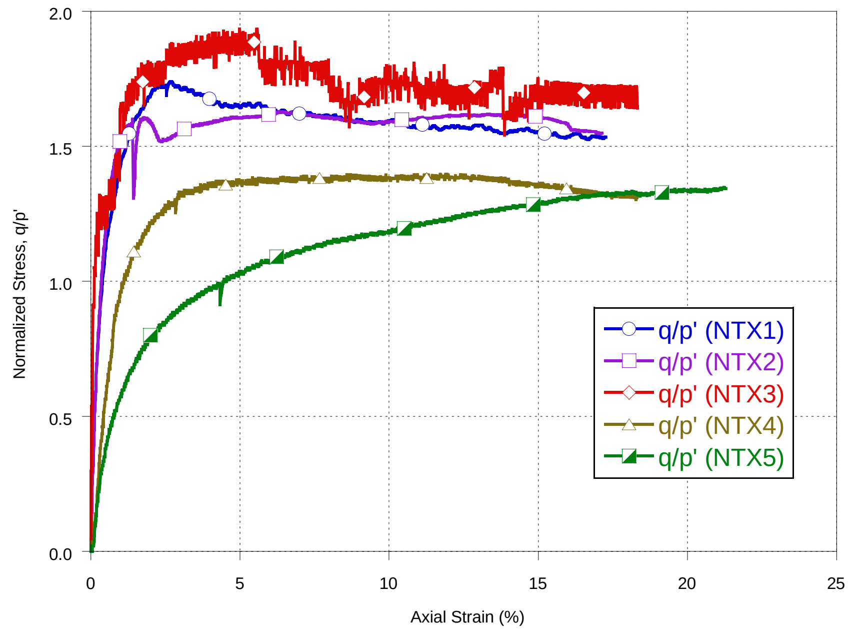


Figure 65. Normalized stress strain curves illustrating the variation in behavior between specimens.

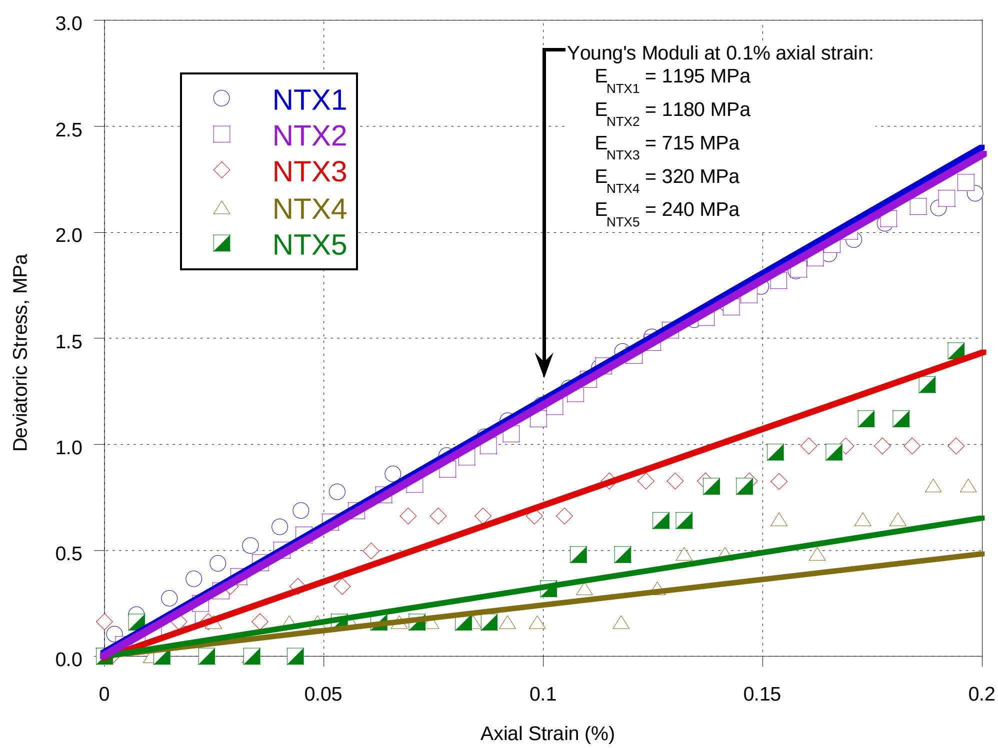


Figure 66. Young’s Modulus calculation for oil sands specimens

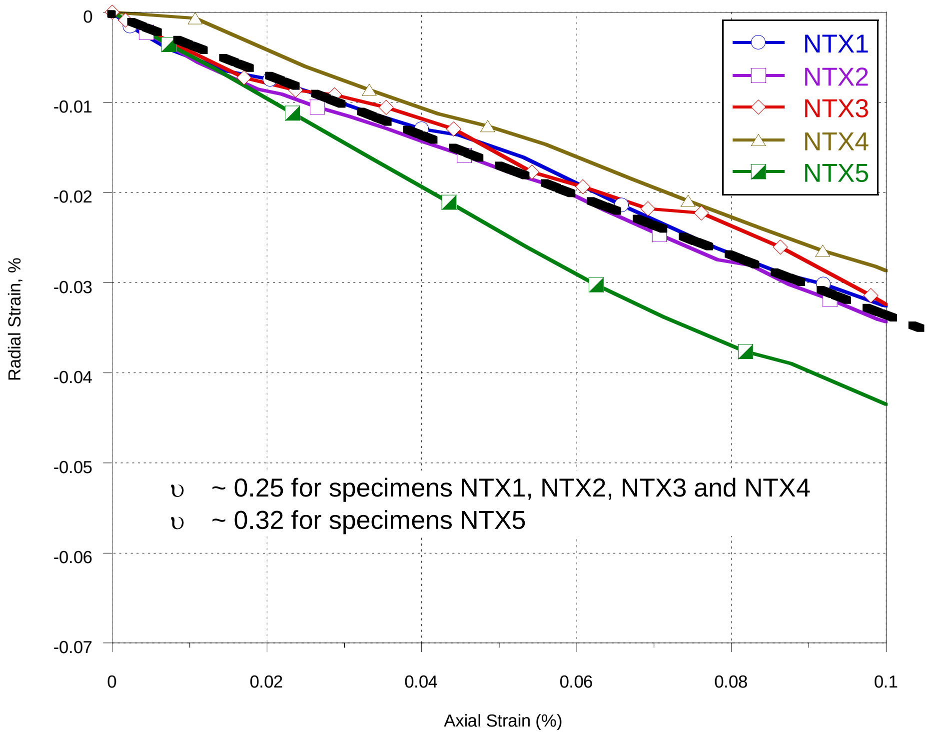


Figure 67. Poisson ratio calculation for oil sands specimens

For the calculation of friction angle, it is assumed that for the oil sands specimens that have undergone bitumen flushing, negligible cohesion is present in the specimens. Consequently, the friction angle is computed using the following:

$$q/p' = M = 6 \sin \phi' / (3 - \sin \phi') \quad [1]$$

For the shear test results shown in Figure 65, it is assumed (based on sample conditions, pre-shear void ratios, volumetric response, etc.) that the normalized stress-strain response exhibited by specimen NTX1 best represents the stress strain response of the Leismer oil sands material. From Figure 65, then, the peak and residual q/p' ratios are:

$$q/p'_{peak} = 1.74$$
$$q/p'_{residual} \sim 1.50$$

Based on these values, the peak and residual friction angles are computed to be:

$$\phi'_{peak} = 42^\circ$$
$$\phi'_{residual} = 37^\circ$$

5.2. Shale Triaxial Tests

5.2.1. General Test Procedure

A nominal 63mm diameter and 127mm height specimen is carefully prepared using a cutting ring and a sharp knife. To prevent drying of the specimen during this process, a light coating of mineral oil is applied to the exposed surfaces of the specimen. The specimen dimensions and weight are recorded and the specimen is placed between two end caps and saturated sintered stainless steel porous stones. Drainage lines are saturated with 3000ppm salinity fluid and two latex membranes are installed around the specimen and endcaps. The triaxial cell is then filled with mineral oil which serves as the medium for applying confining pressure. The cell is placed within a high pressure triaxial loading frame. Final assembly of the cell is completed by connecting with back pressure system and cell pressure system.

All external drainage lines and instrumentation are connected at this point and both confining pressure and back pressure (pore pressure) are applied. An LVDT is attached to the loading ram to monitor the vertical strain.

A seating load of 50 kPa is applied. Incrementally, the back (pore) pressure and the cell pressure are increased to 5.0 MPa and 5.05 MPa, respectively. The mean effective confining stress of 50 kPa is maintained overnight to allow consolidation and saturation of the specimen.

To reach the stress conditions specified for each test, the cell pressure is increased (and decreased, if necessary) while maintaining the pore pressure at 5.0 MPa. Successive load increments are applied once consolidation has ceased.

For undrained shear, the back pressure valve is closed to created undrained conditions within the specimen. The compression machine is set at the desired axial strain rate of 0.004mm/min. Load and deformation readings are continuously recorded by the data acquisition system. At the conclusion of the shear test, the compression machine is stopped, the back and cell pressures are released and the triaxial cell is removed from the loading frame. The cell is then carefully disassembled and specimen is preserved in the moisture room.

Regarding nomenclature, the following definitions for p’ and q has been used in presenting all triaxial test results:

$$p' = (\sigma_1' + 2\sigma_3')/3$$

$$q = (\sigma_1' - \sigma_3')$$

5.2.2. Test ST1: p_o’ = 0.71 MPa

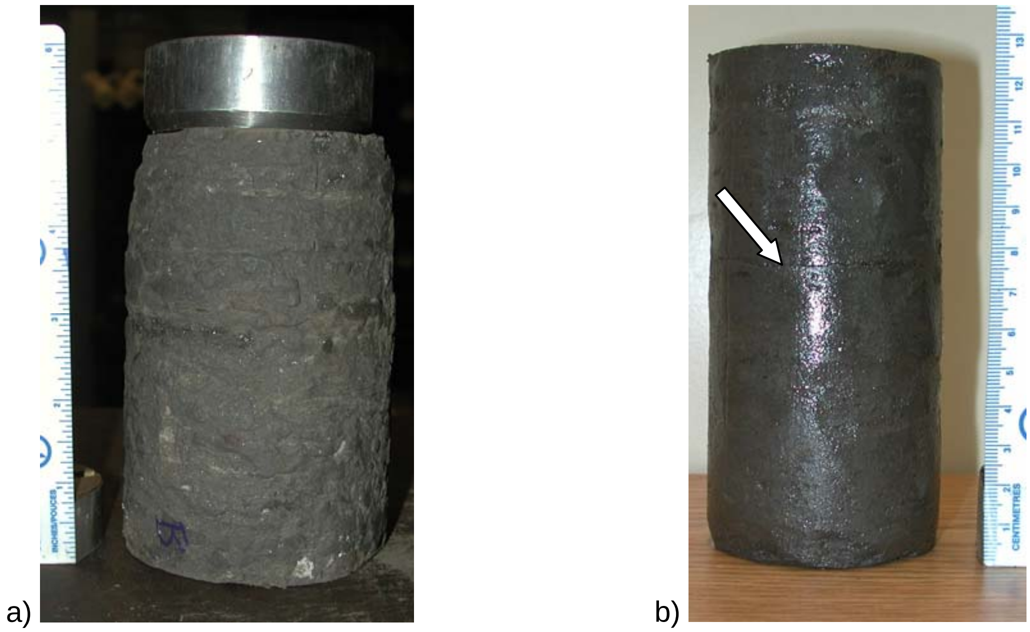


Figure 68. ST1 test specimen a) just after removal from liner b) after cutting (arrow denotes location of horizontal fracture in specimen)

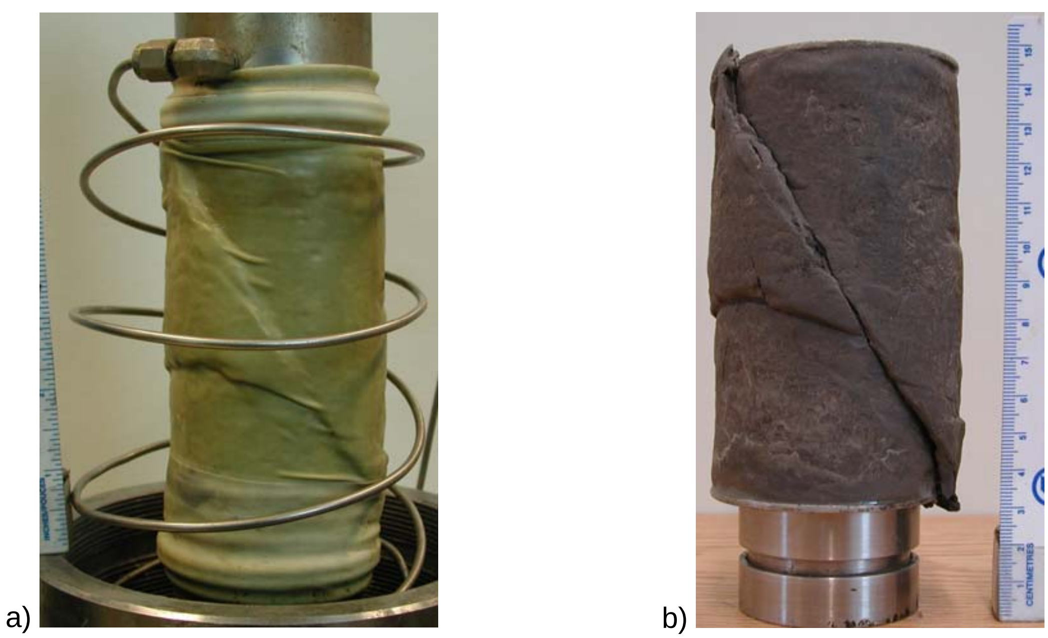


Figure 69. ST1 test specimen a) post-test specimen still inside membrane b) post-test specimen with membrane removed showing deformed state of specimen

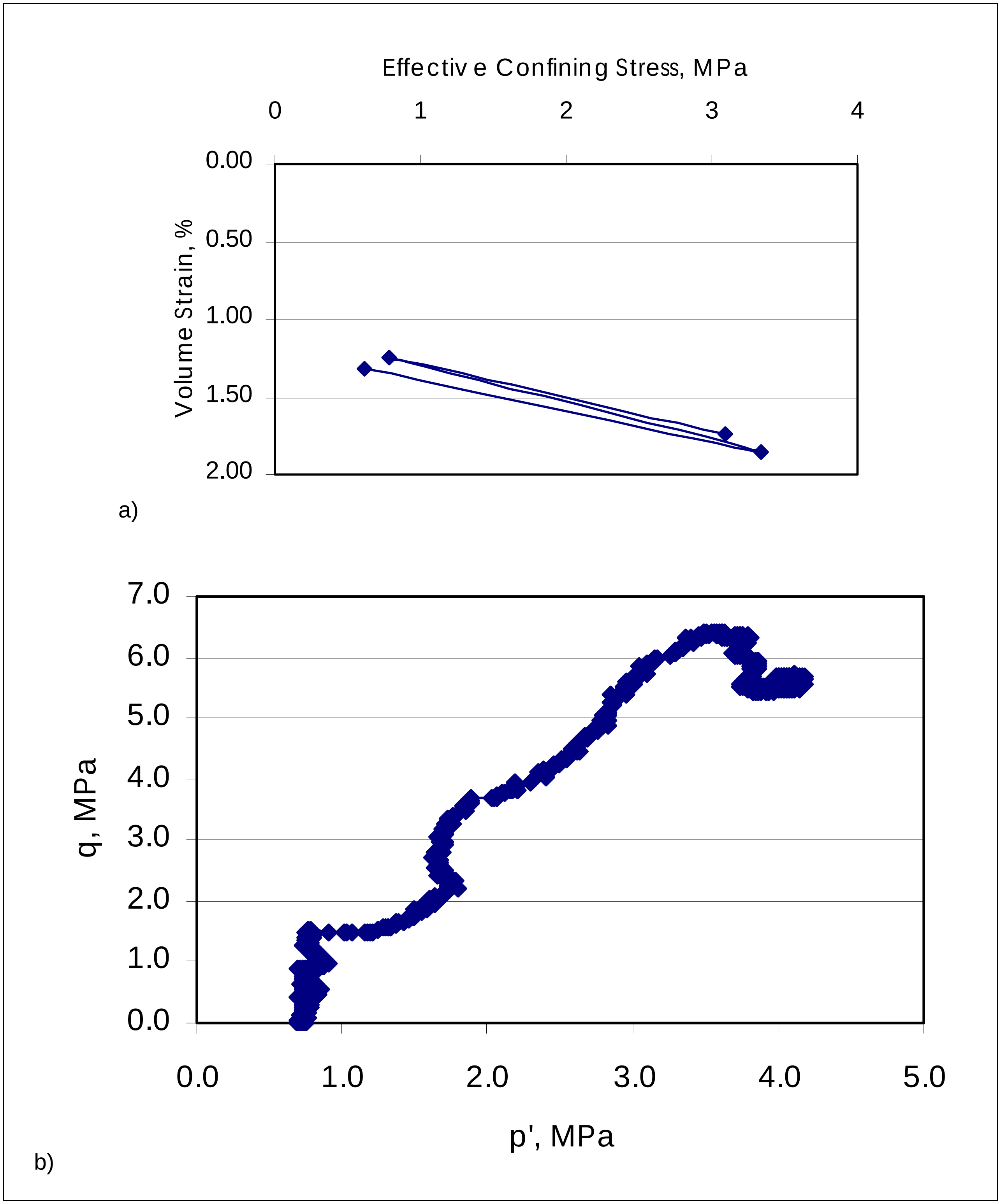


Figure 70. ST1 triaxial test results a) compressibility b) stress path

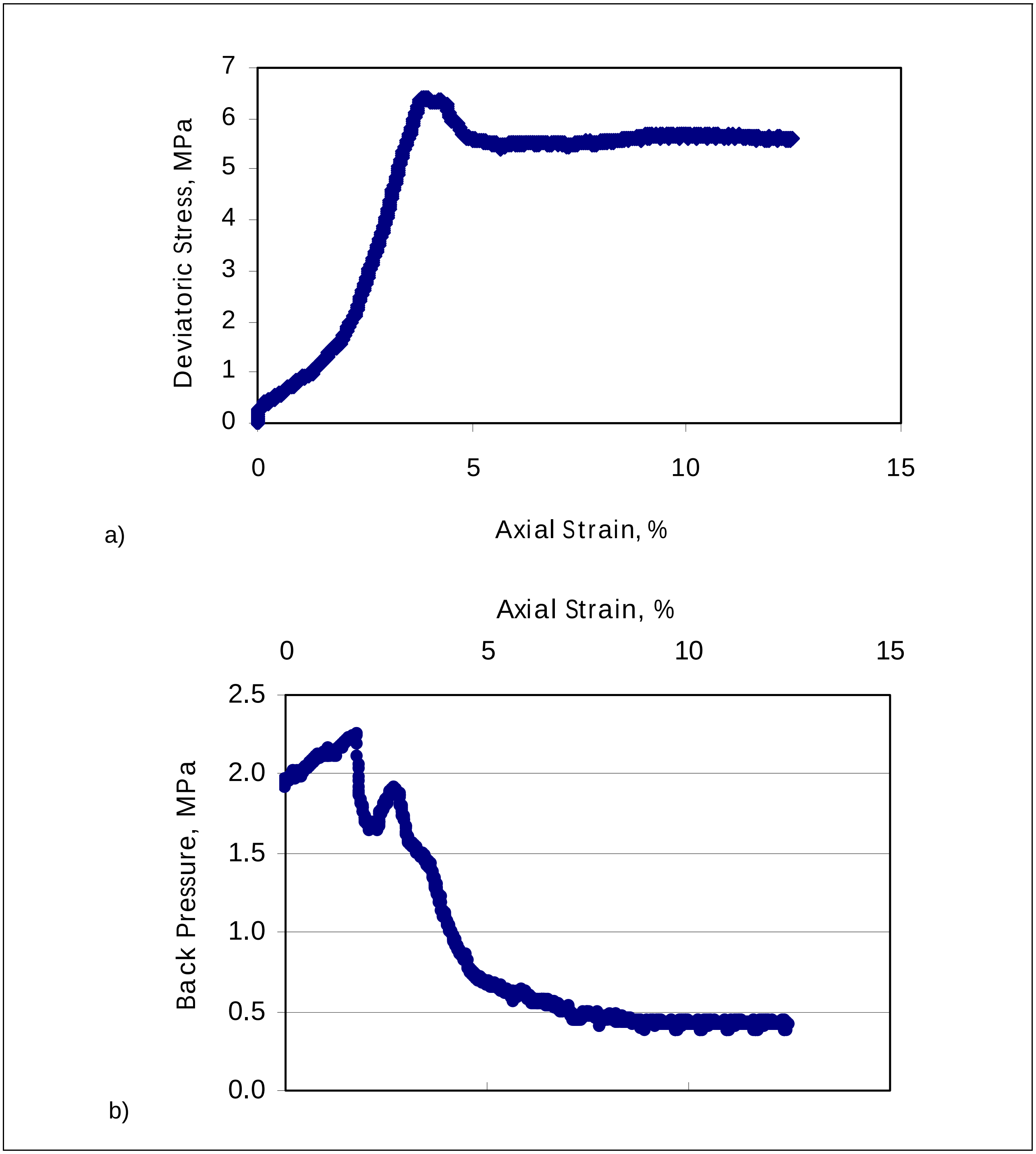


Figure 71. ST1 triaxial test results a) stress-strain b) volume change

Permeability Calculation

Flow Rate mL/min	Initial Pressure MPa	Perm. Pressure MPa	Diff. Pressure kPa	Sample Height cm	Void Ratio	X-area cm2	k=QH/p/A cm/s	Permeability μ **Darcy**
0.0003	0.415	1.02653	611.5	11.173	0.20842	35.86	2.49E-10	**0.2592**

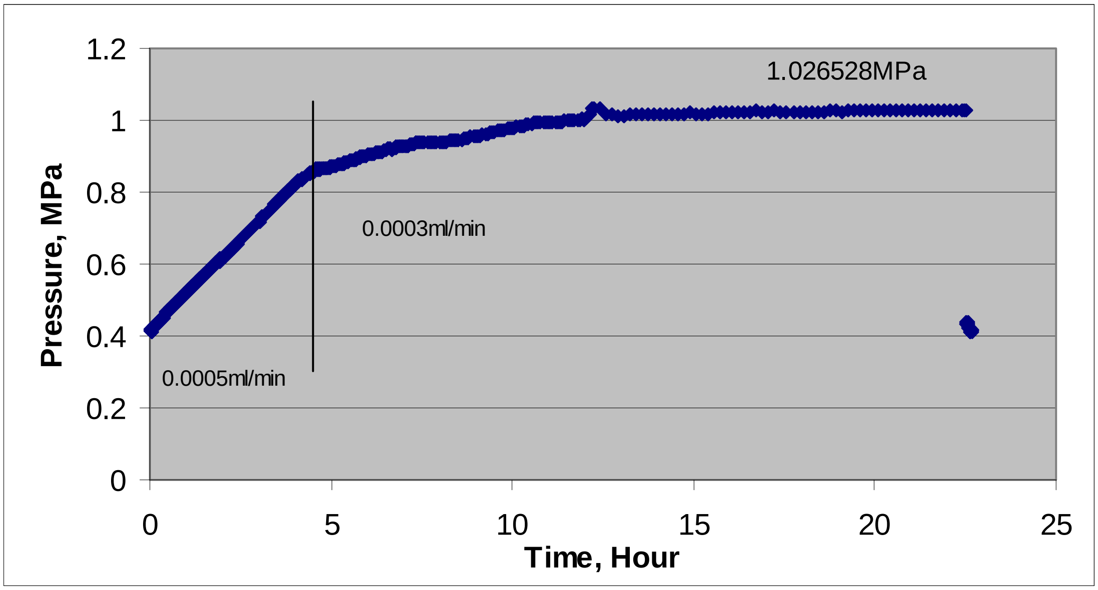


Figure 72. ST1 permeability test results

5.2.3. Test ST2: $p_o' = 1.06$ MPa

a) 

b) 

Figure 73. ST2 test specimen a) just after removal from liner b) after cutting specimen

a) 

b) 

Figure 74. ST2 test specimen a) post-test specimen still inside membrane b) post-test specimen with membrane removed showing deformed state of specimen

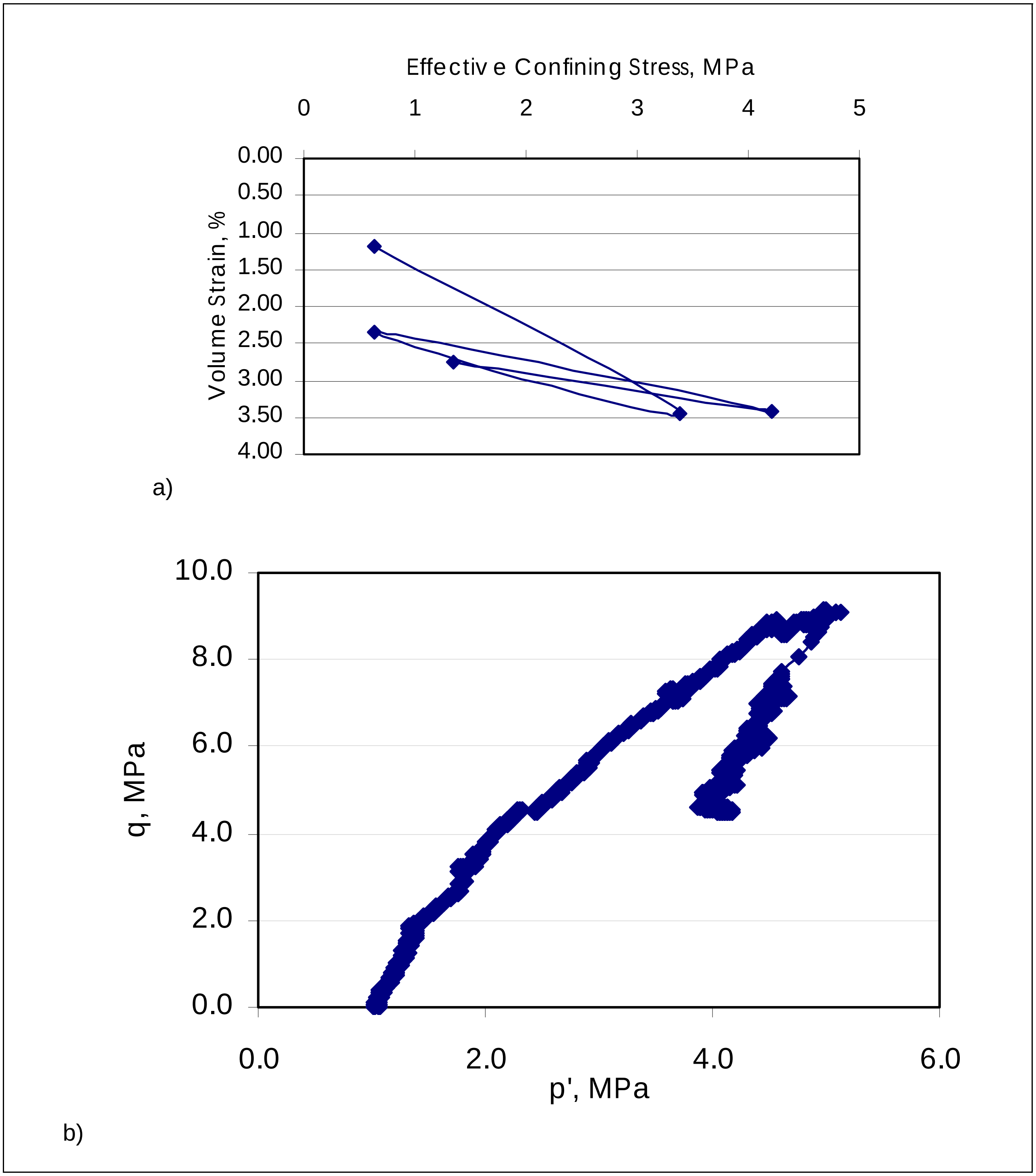


Figure 75. ST2 triaxial test results a) compressibility b) stress path

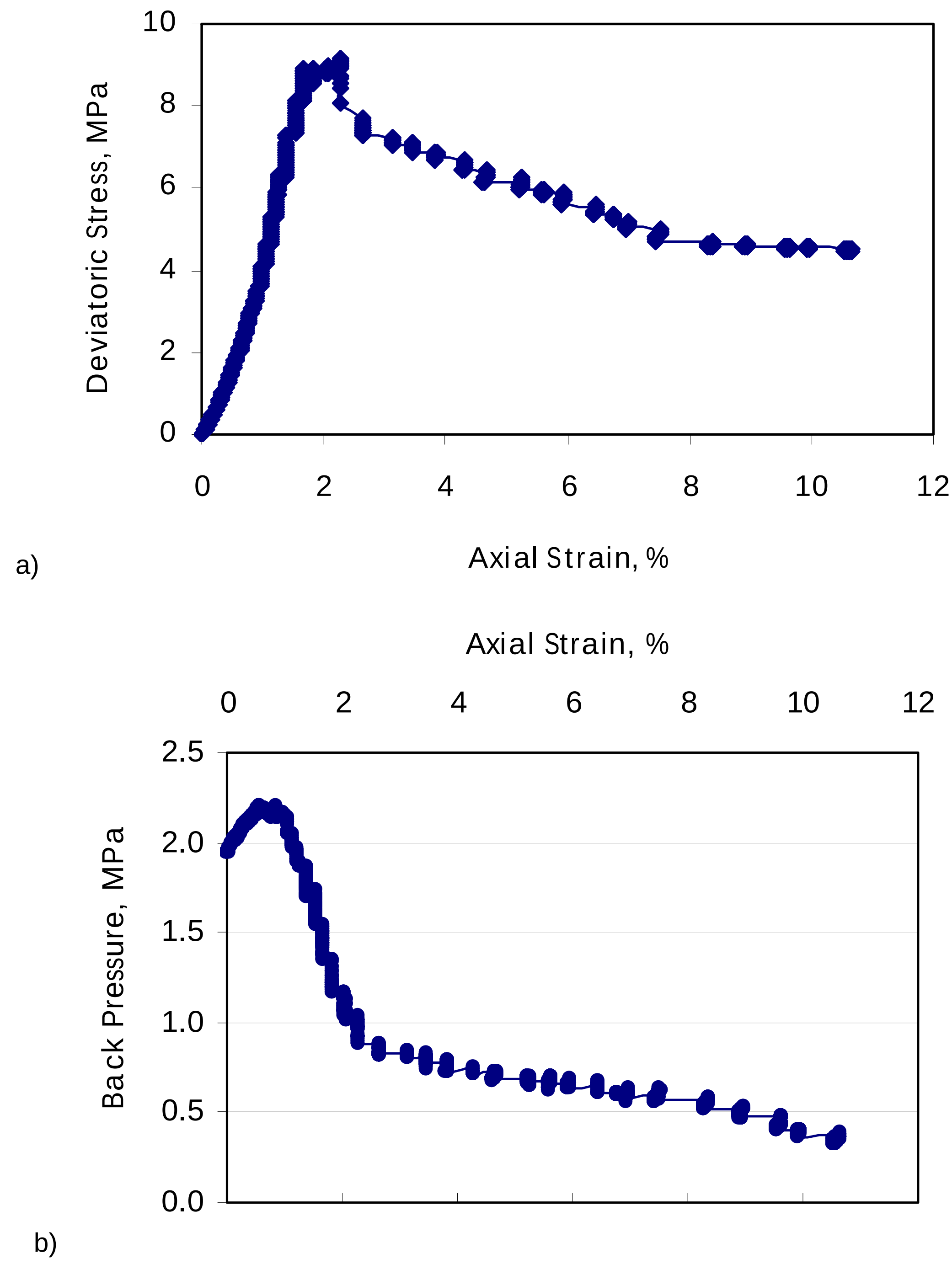


Figure 76. ST2 triaxial test results a) stress-strain b) volume change

Permeability Calculation

Flow Rate mL/min	Initial Pressure MPa	Perm. Pressure MPa	Diff. Pressure kPa	Sample Height cm	Void Ratio	X-area cm2	k=QH/p/A cm/s	Permeability μ Darcy
0.001	0.365	0.94849	583.5	11.869	0.24596	33.76	9.83E-10	**1.0220**

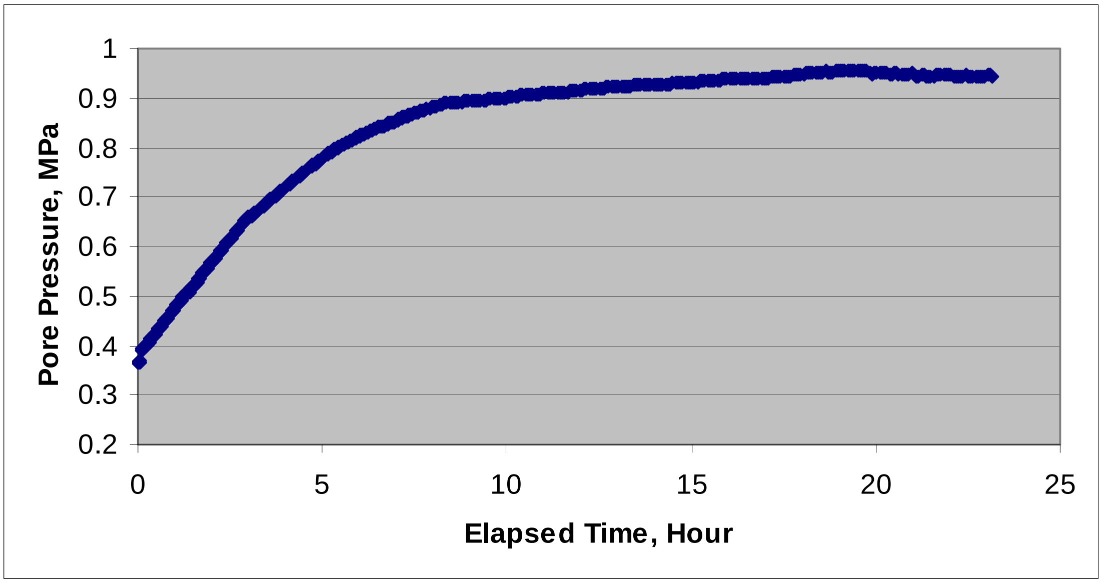


Figure 77. ST2 permeability test results

5.2.4. Test ST3: p_o' = 0.96 MPa

a) b)

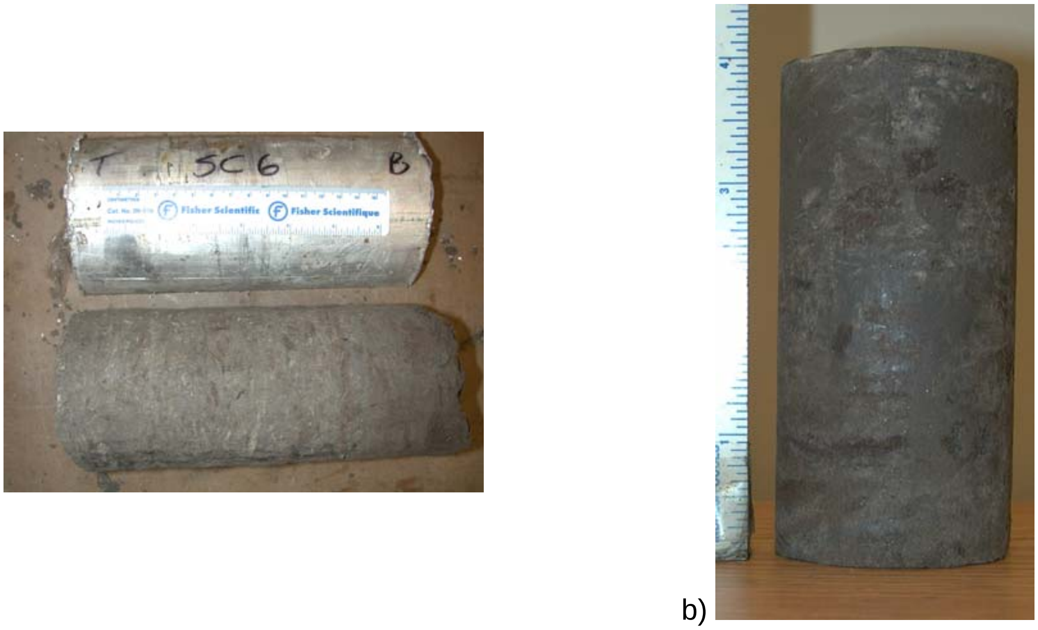


Figure 78. ST3 test specimen a) just after removal from liner b) after cutting specimen

a) b)

Figure 79. ST3 test specimen a) post-test specimen still inside membrane b) post-test specimen with membrane removed showing deformed state of specimen

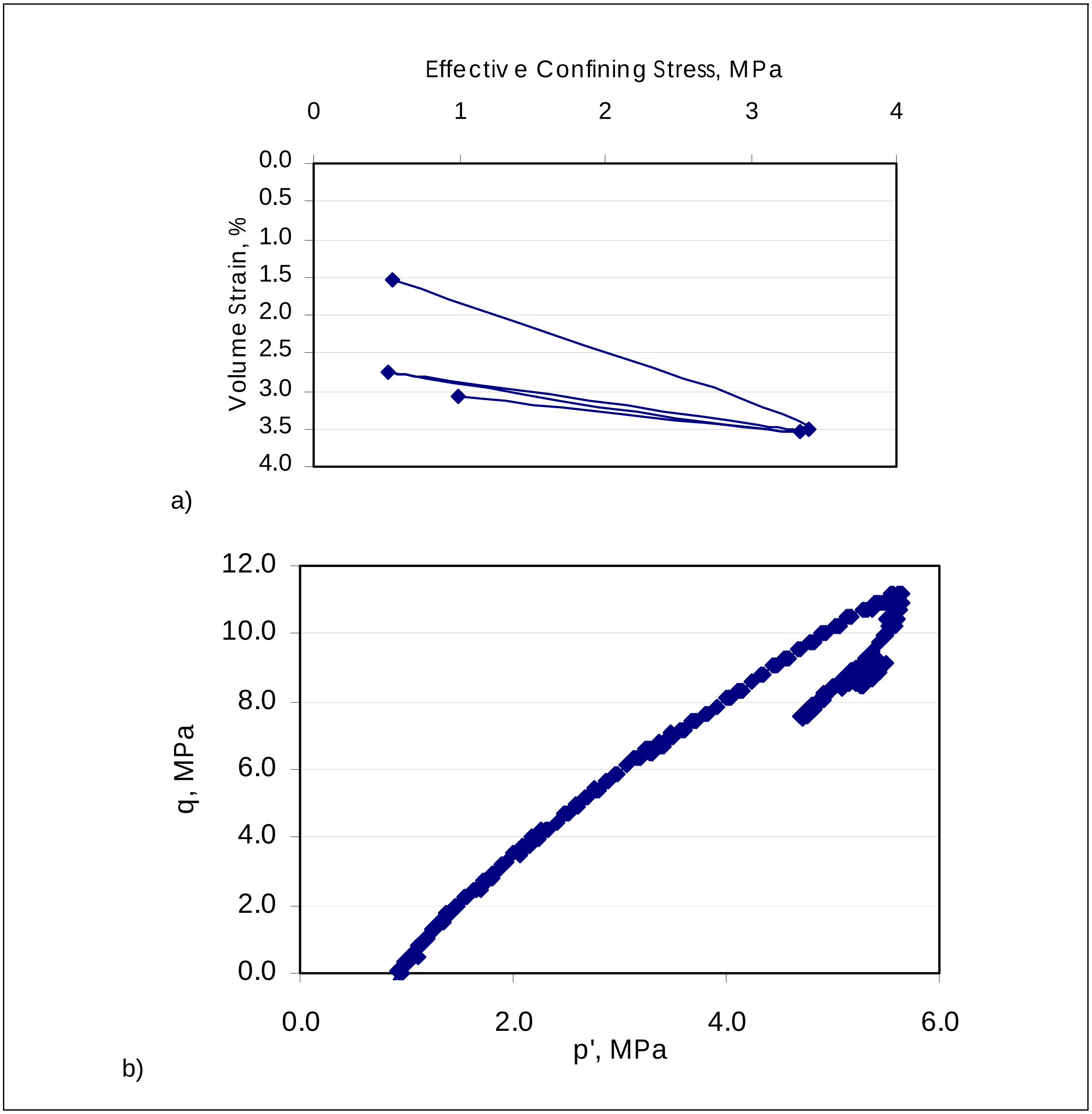


Figure 80. ST3 triaxial test results a) compressibility b) stress path

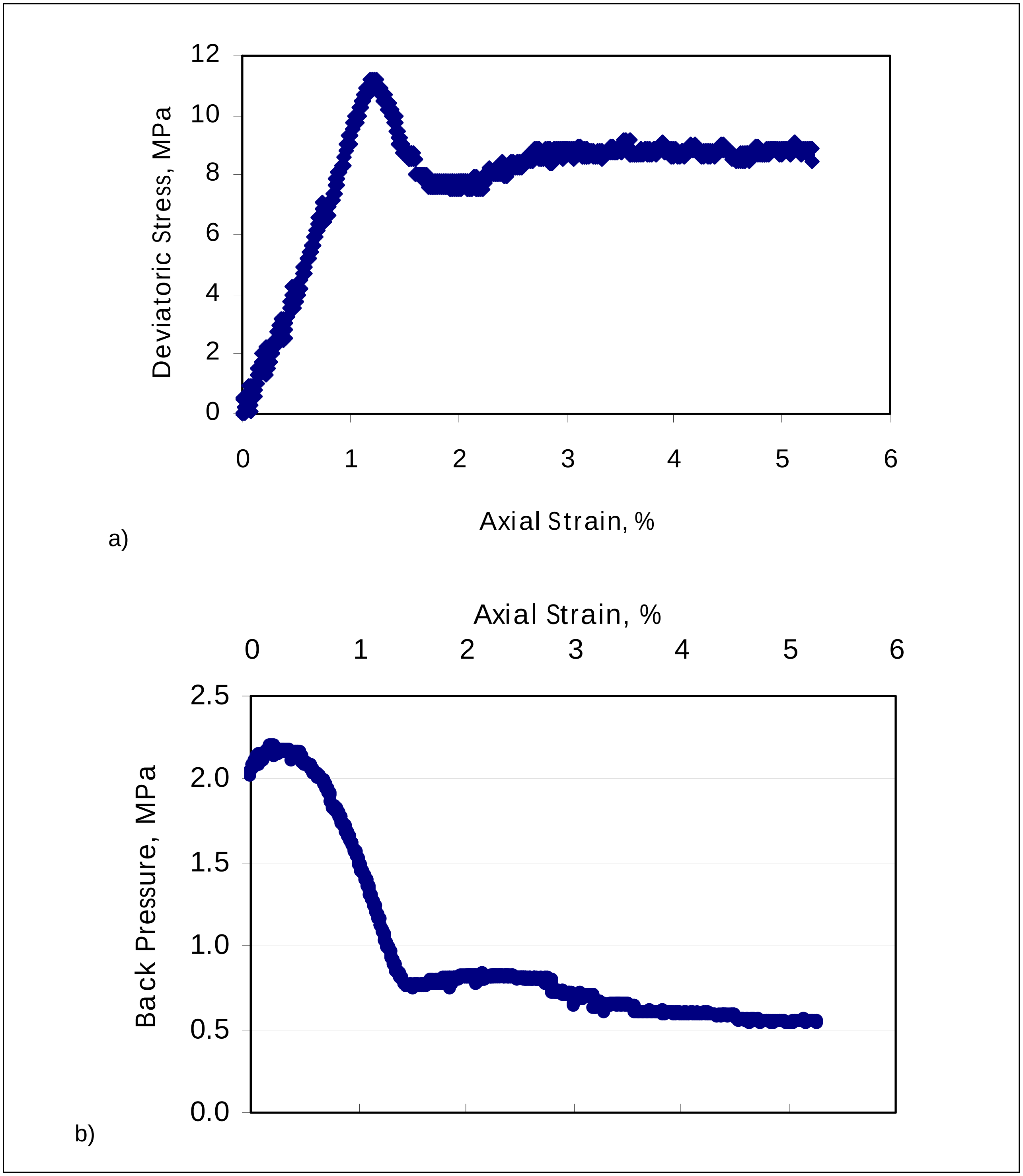


Figure 81. ST3 triaxial test results a) stress-strain b) volume change

Permeability Calculation

Flow Rate mL/min	Initial Pressure MPa	Perm. Pressure MPa	Diff. Pressure kPa	Sample Height cm	Void Ratio	X-area cm2	k=QH/p/A cm/s	Permeability μ **Darcy**
0.001	0.489	0.635	145.6	9.700	0.21706	21.65	5.02E-09	**5.2168**
0.002	0.489	0.764	274.8	9.700	0.21706	21.65	5.32E-09	**5.5298**
0.004	0.489	1.026	536.9	9.700	0.21706	21.65	5.44E-09	**5.6604**

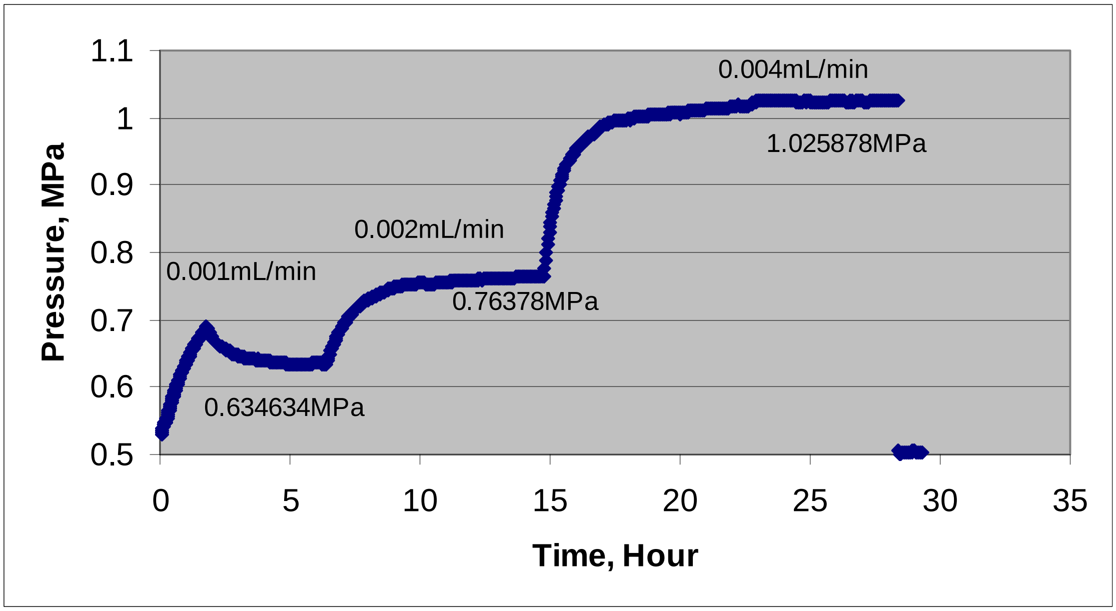
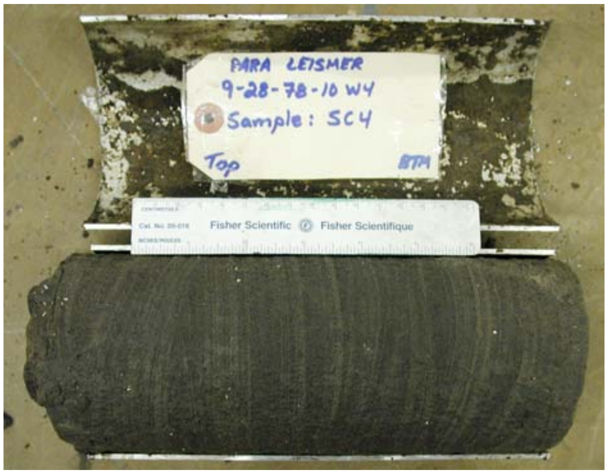


Figure 82. ST3 permeability test results

5.2.5. Test ST4: p_o' = 4.53 MPa

a) 

b) 

Figure 83. ST4 test specimen a) just after removal from liner b) after cutting (lithology of sample made cutting of specimen difficult, as evidenced by uneven exterior of specimen)

a) 

b) 

Figure 84. ST4 test specimen a) post-test specimen still inside membrane b) post-test specimen with membrane removed showing deformed state of specimen

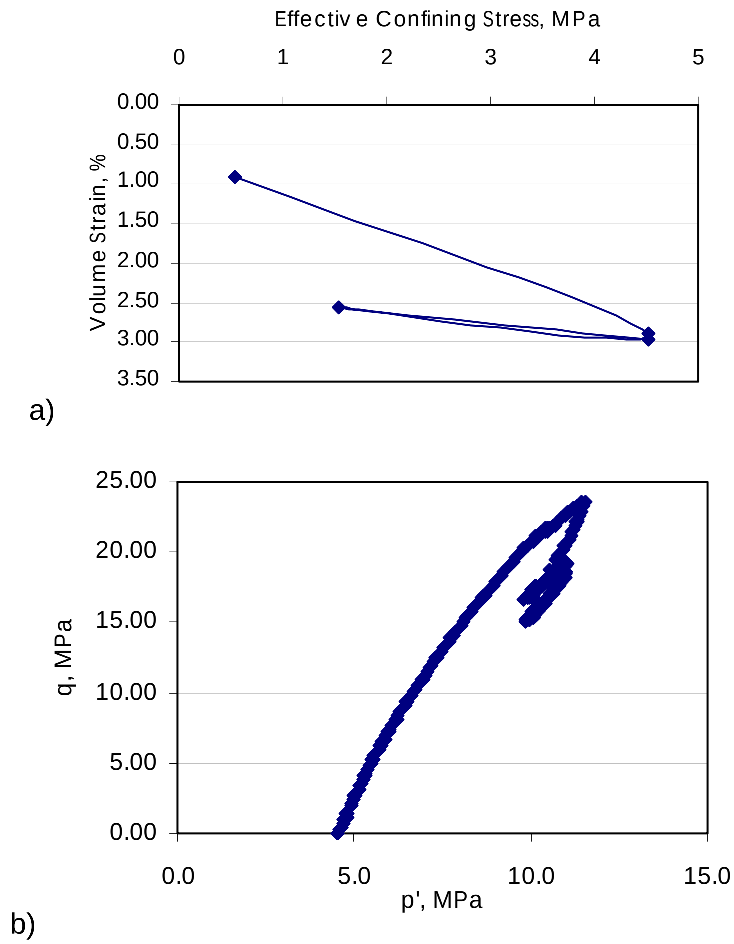


Figure 85. ST4 triaxial test results a) compressibility b) stress path

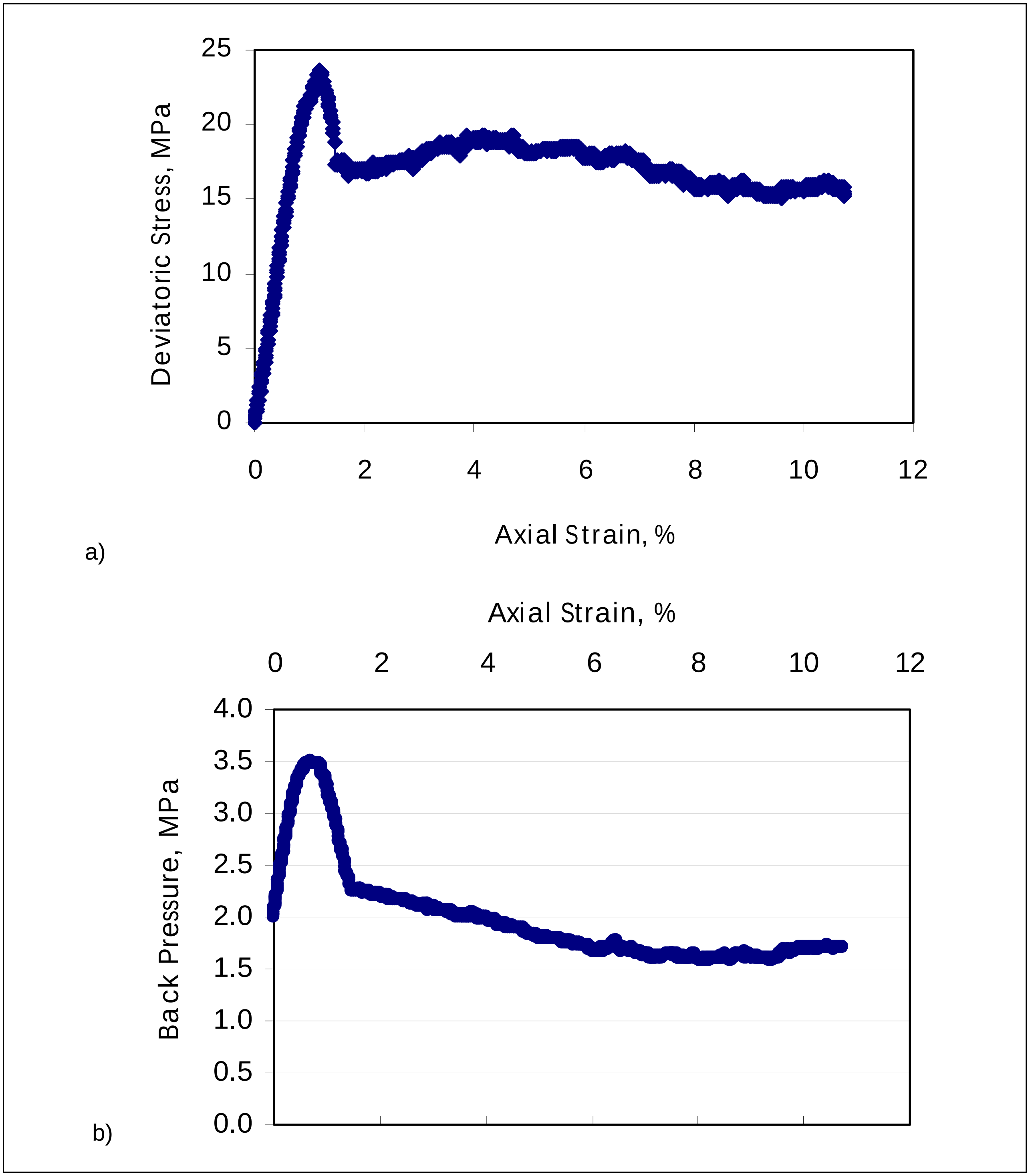


Figure 86. ST4 triaxial test results a) stress-strain b) volume change

Permeability Calculation

Flow Rate mL/min	Initial Pressure MPa	Perm. Pressure MPa	Diff. Pressure kPa	Sample Height cm	Void Ratio	X-area cm2	Permeability k=QH/p/A cm/s	μ Darcy
0.0005	1.705	1.821	115.7	9.168	0.21034	27.98	2.31E-09	**2.4017**
0.001	1.705	1.936	231.4	9.168	0.21034	27.98	2.31E-09	**2.4013**

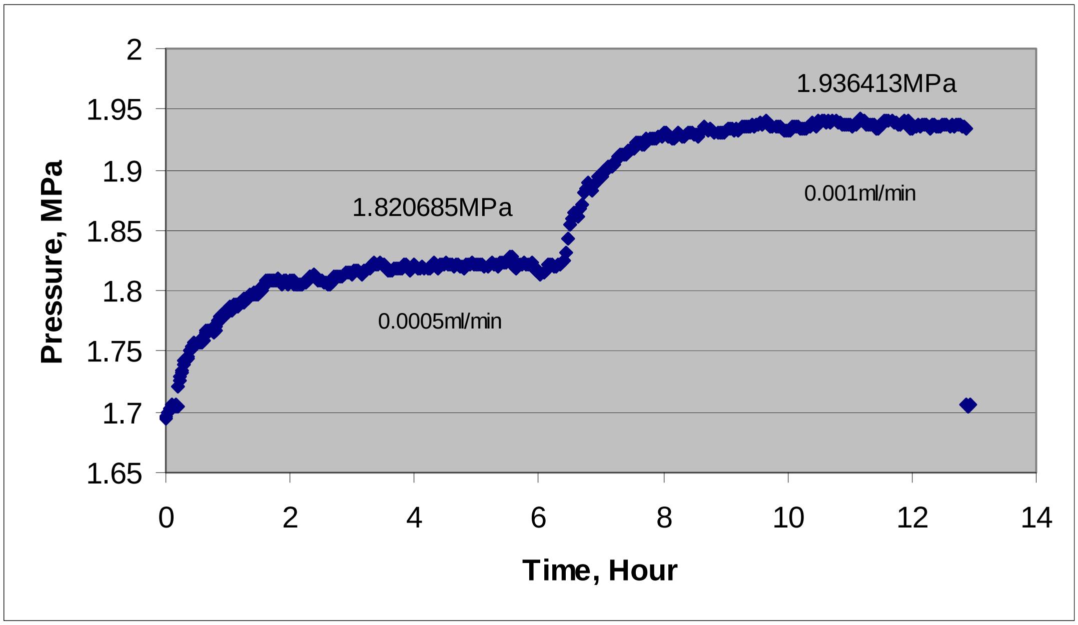


Figure 87. ST4 permeability test results

5.2.6. Test ST5: p_o' = 6.35 MPa

a) no photo

b) 

Figure 88. ST5 test specimen a) just after removal from liner b) after cutting specimen

a) 

b) 

Figure 89. ST5 test specimen a) post-test specimen still inside membrane b) post-test specimen with membrane removed showing deformed state of specimen (contrast enhanced in photo)

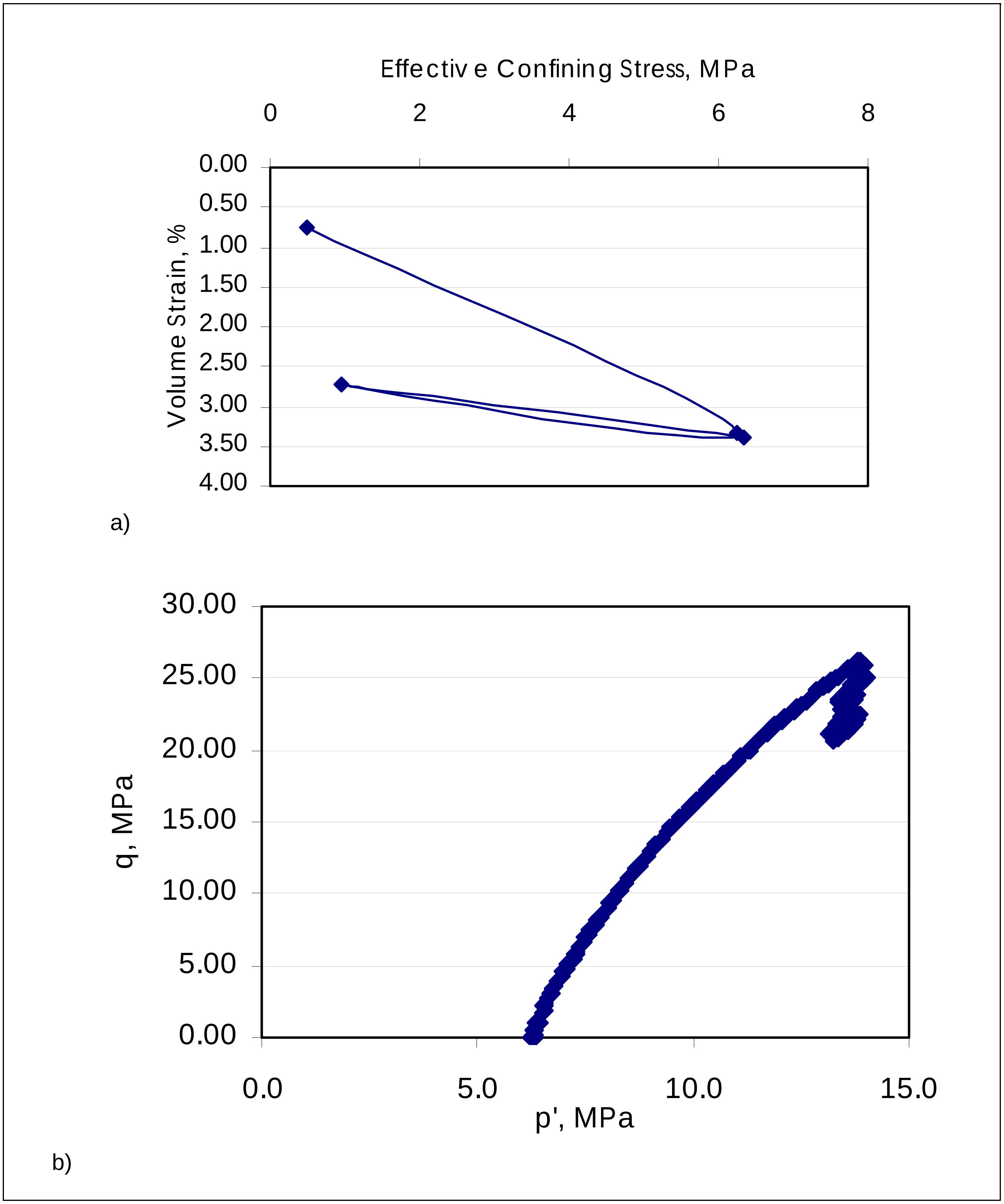


Figure 90. ST5 triaxial test results a) compressibility b) stress path

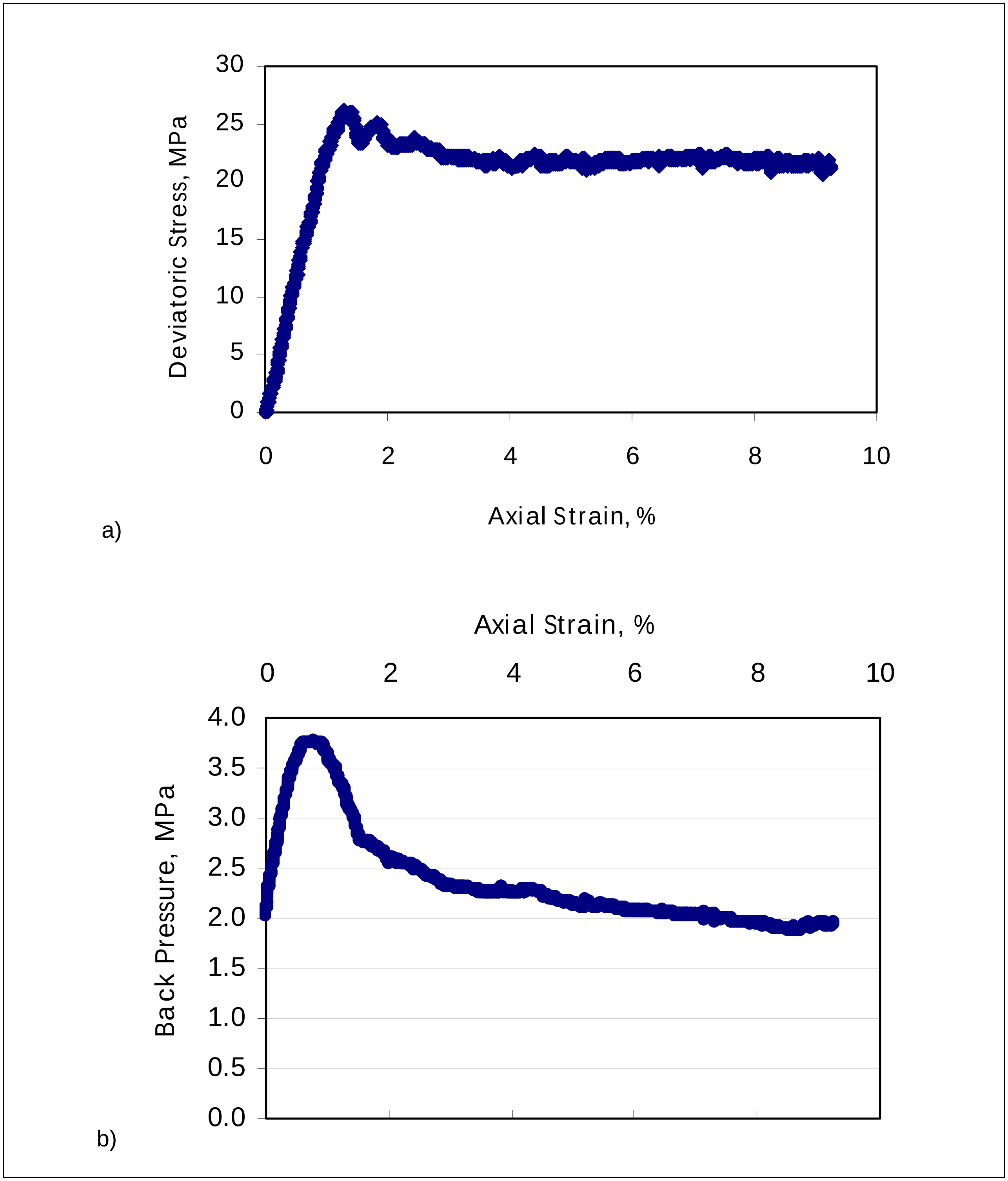


Figure 91. ST5 triaxial test results a) stress-strain b) volume change

Permeability Calculation

Flow Rate mL/min	Initial Pressure MPa	Perm. Pressure MPa	Diff. Pressure kPa	Sample Height cm	Void Ratio	X-area cm2	k=QH/p/A cm/s	Permeability µ Darcy
0.001	1.868	2.367	498.8	9.348	0.21384	22.33	1.37E-09	**1.4237**

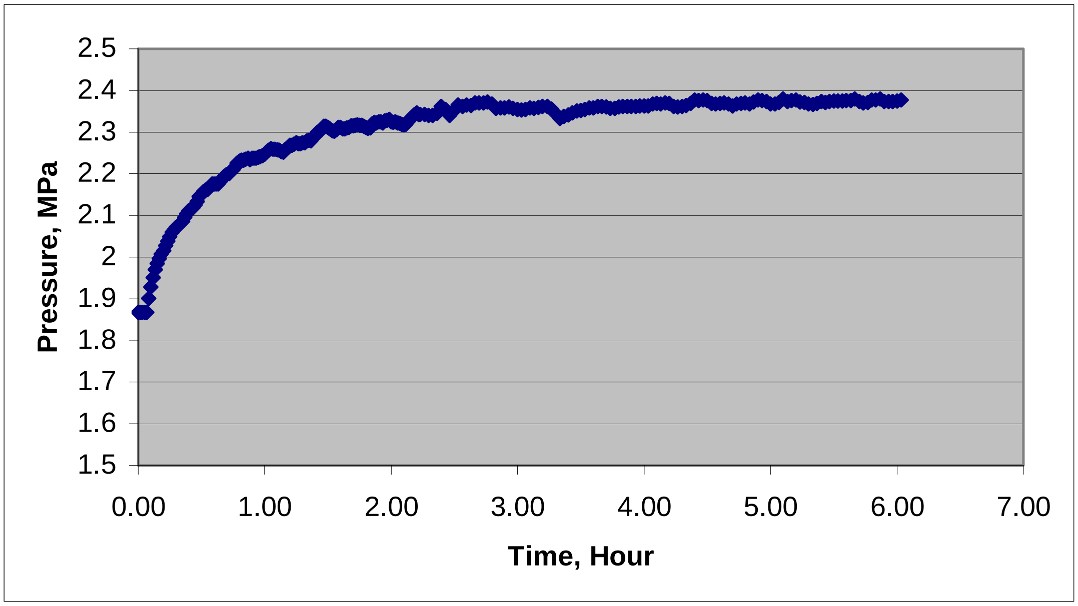


Figure 92. ST5 permeability test results

5.2.7. Test ST6: p_o' = 0.56 MPa

a) no photo

b) 

Figure 93. ST6 test specimen a) just after removal from liner b) after cutting specimen

a) 

b) 

Figure 94. ST6 test specimen a) post-test specimen still inside membrane b) post-test specimen with membrane removed showing deformed state of specimen

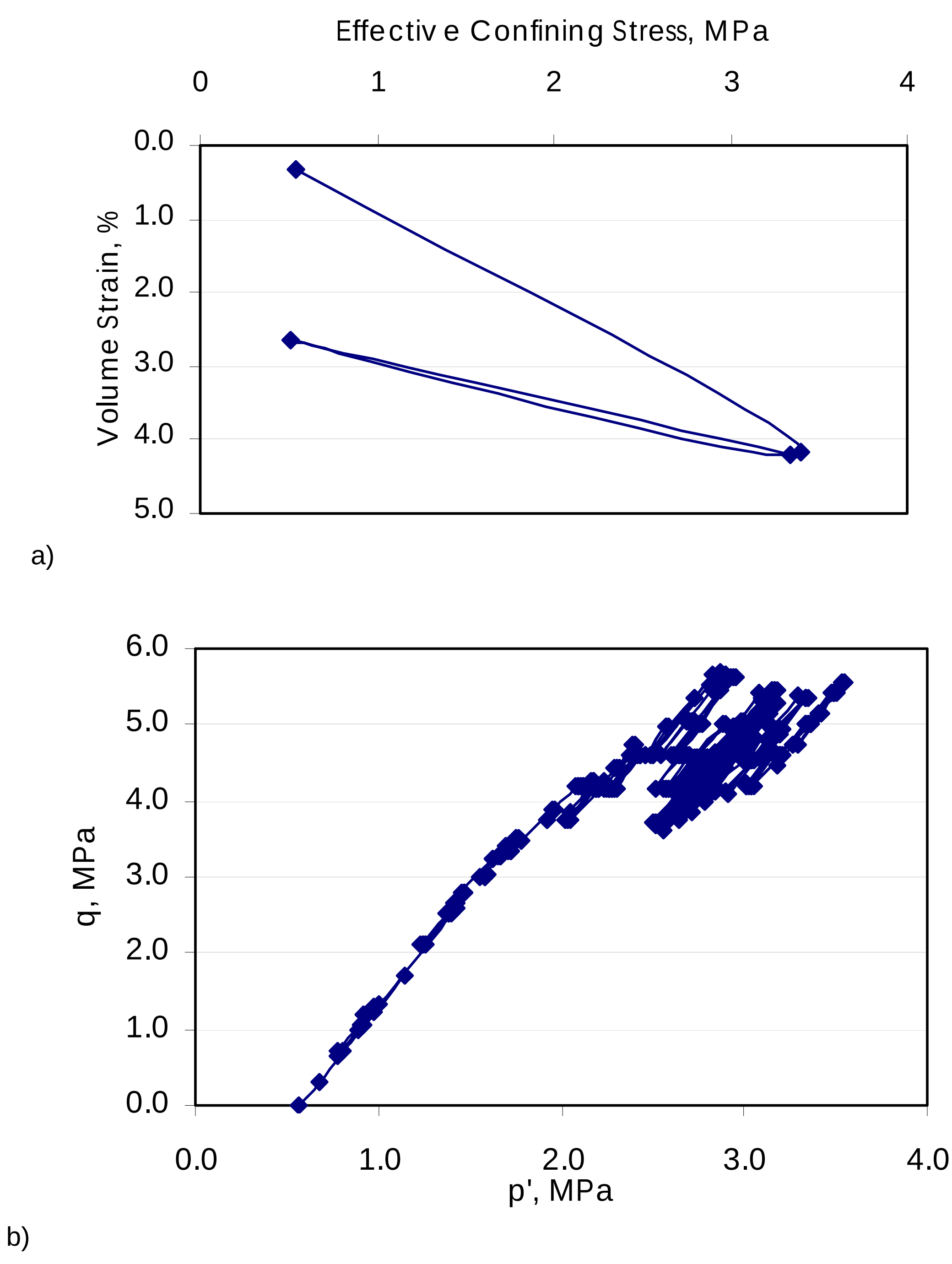


Figure 95. ST6 triaxial test results a) compressibility b) stress path

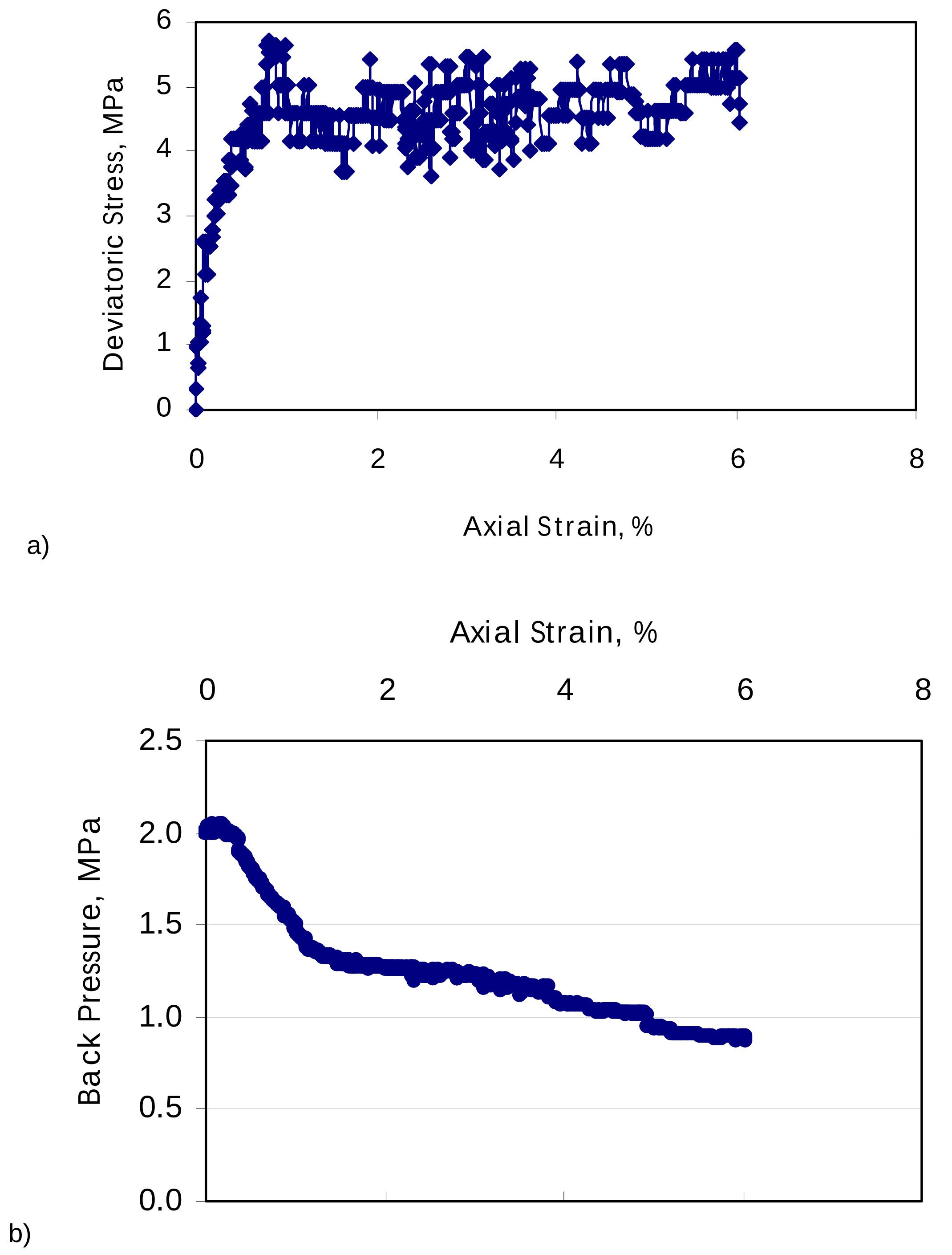


Figure 96. ST6 triaxial test results a) stress-strain b) volume change

Permeability Calculation

Flow Rate mL/min	Initial Pressure MPa	Perm. Pressure MPa	Diff. Pressure kPa	Sample Height cm	Void Ratio	X-area cm2	Permeability k=QH/p/A cm/s	μ **Darcy**
0.002	0.882	2.231	1348.6	7.729	0.21992	11.97	1.56E-09	**1.6240**

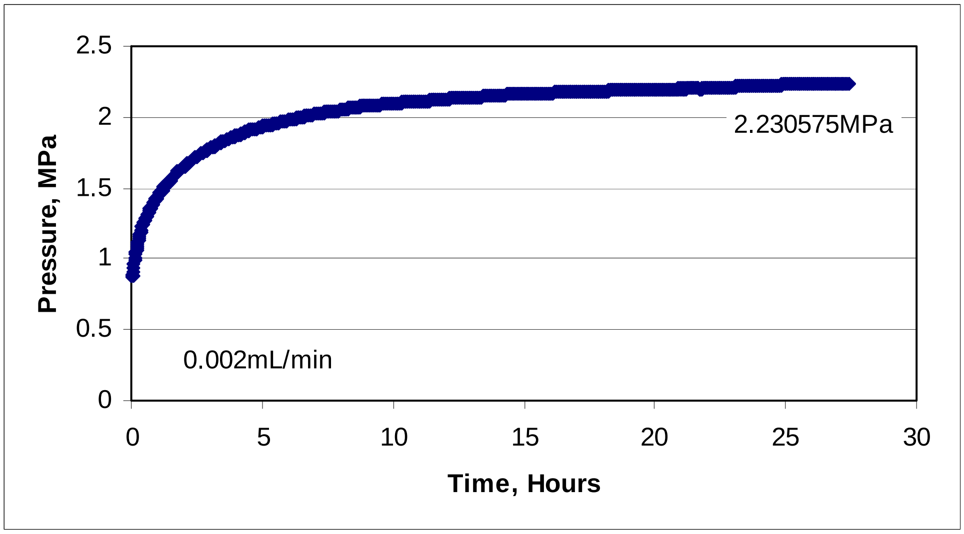


Figure 97. ST6 permeability test results

5.2.8. Summary of Shale Triaxial Tests

Figures 98, 99, and 100 provide summary plots of the triaxial tests completed on the shale specimens.

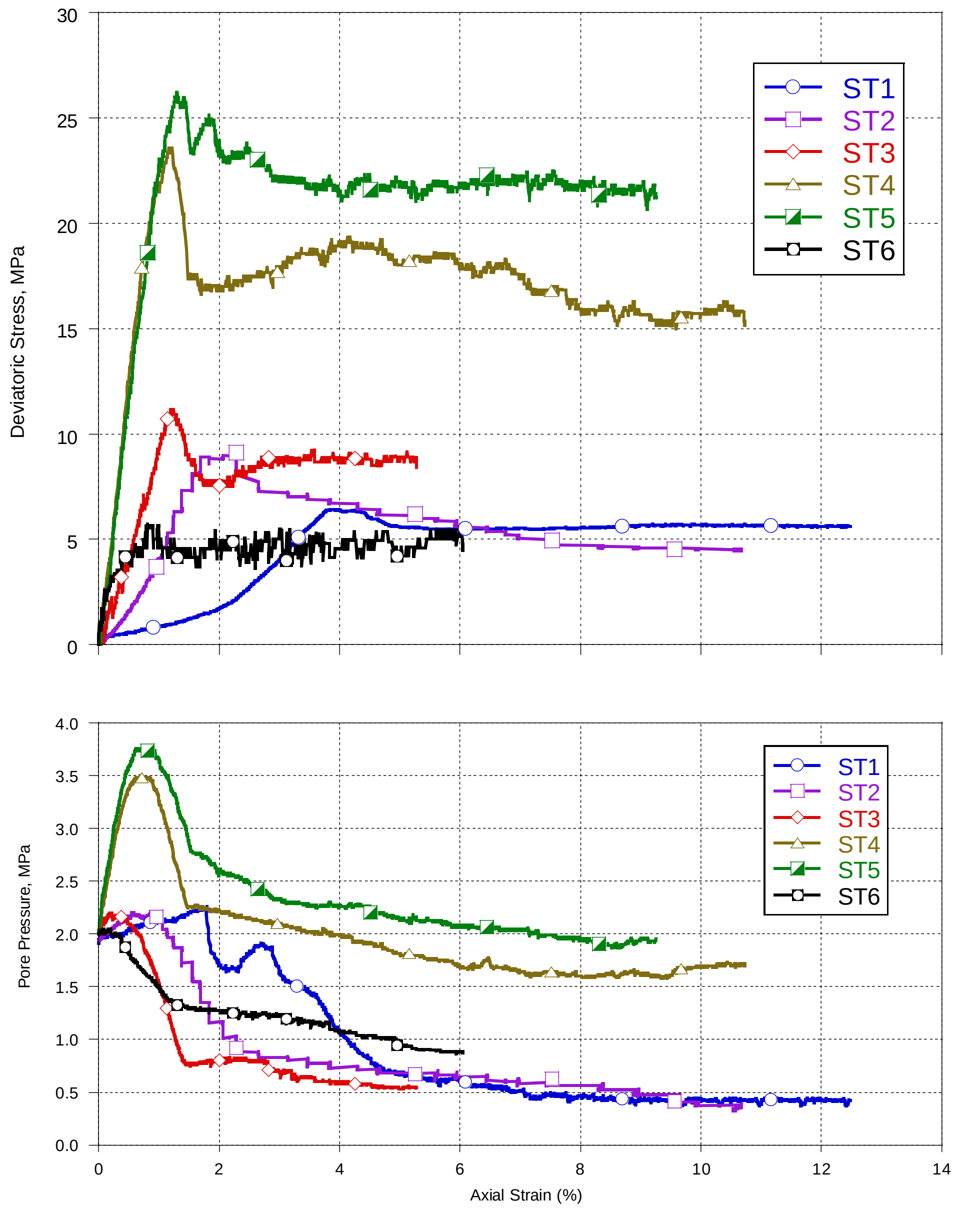


Figure 98. Summary of all shale triaxial test results

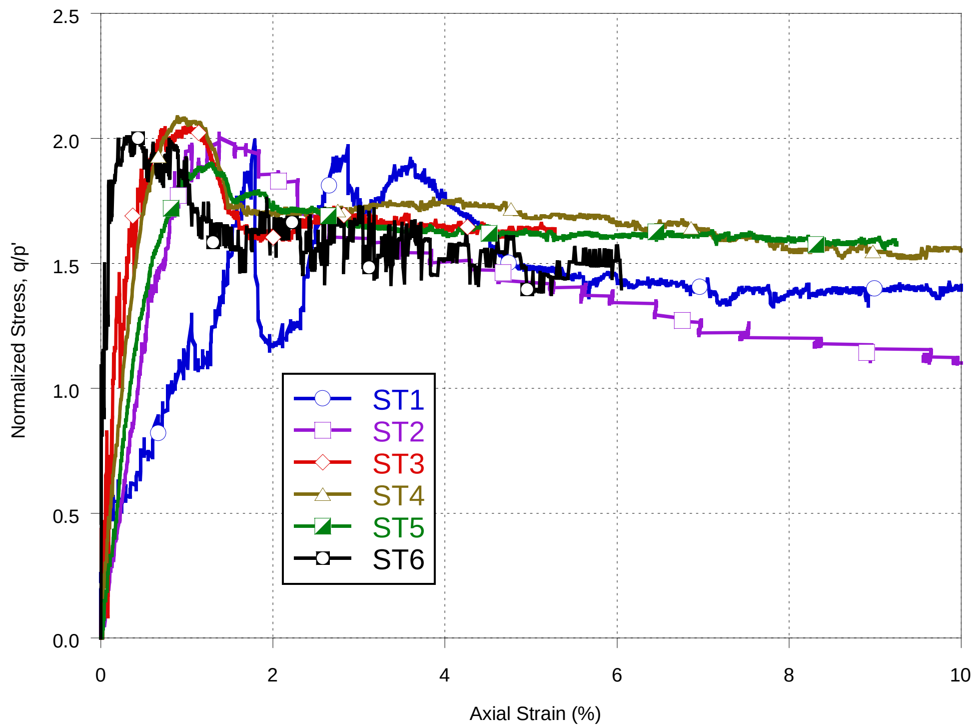


Figure 99. Normalized stress strain curves illustrating the variation in behavior between shale specimens.

Examination of the results shown in Figure 99 would suggest that the test results for ST1 should be excluded from all calculations, even though its first peak q/p' corresponds well with the other shale samples. Based on the results shown in Figure 99, it is assumed that peak shear strength can be reasonably represented by a q/p' value of 2.0 and the residual shear strength is reflected by a q/p' value of 1.50. Consequently, the friction angle can computed using the following:

$$q/p' = M = 6 \sin \phi' / (3 - \sin \phi')$$

and using

$$q/p'_{peak} \sim 2.0$$
$$q/p'_{residual} \sim 1.50$$

the peak and residual friction angles are computed to be:

$$\phi'_{peak} = 48\,^{\circ}$$
$$\phi'_{residual} = 37\,^{\circ}$$

To check these results, the stress strain data was replotted in terms of s' and t, which are alternate measures of mean stress and shear stress. Figure 100 illustrates the s'-t plot for tests ST1, ST2, ST3, ST4, ST5 and ST6. In this version of the stress path space, the following relationships can be used to compute the Mohr-Coulomb strength parameters:

$$\tan \psi = \sin \phi$$

$$d = c' \cos \phi$$

and using $d_{pk} = 0$ MPa ; $d_{res} = 0$ MPa

$\psi_{pk} = 35.9^{o}$; $\psi_{res} = 31.3^{o}$

the peak and residual friction angles are computed to be:

$$\phi'_{peak} = 46.4\,°$$
$$\phi'_{residual} = 37.5\,°$$

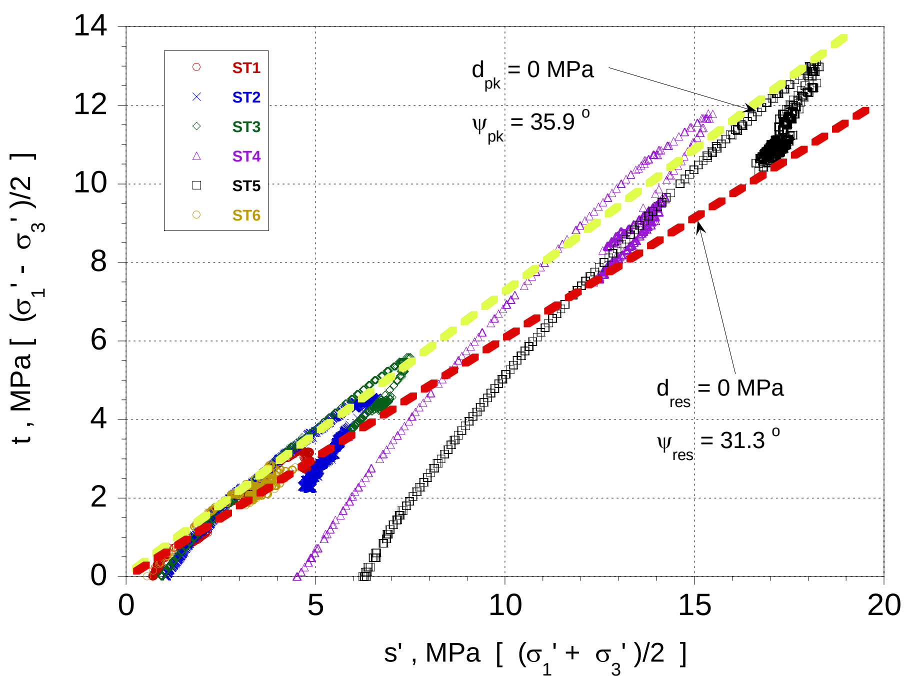


Figure 100. Stress path plot (s'-t) for shale specimen CU test results.

Based on the results shown in Figure 100, all the shale specimens are displaying moderately overconsolidated behavior, even at mean effective confining stresses above 5.0 MPa.

5.2.9. Summary of Shale Permeability Tests

Figure 101 summarizes the results obtained for the permeability test conducted on the shale specimens. The results of specimen ST1 have not been used in this figure due to its inconsistent shear behavior. As shown in Figure 101, no clear relationship exists for the post-test permeability results. On average, the post-shear permeability was approximately 2 μD. This is a very small permeability and suggests that throughout the shear process, no discrete discontinuities are created within these sandy shale specimens that enhance the permeability substantially. It would be prudent to conduct a series of tests both pre- and post-shear if not during the shearing process (for drained shear tests) to fully understand the evolution of permeability within this class of materials.

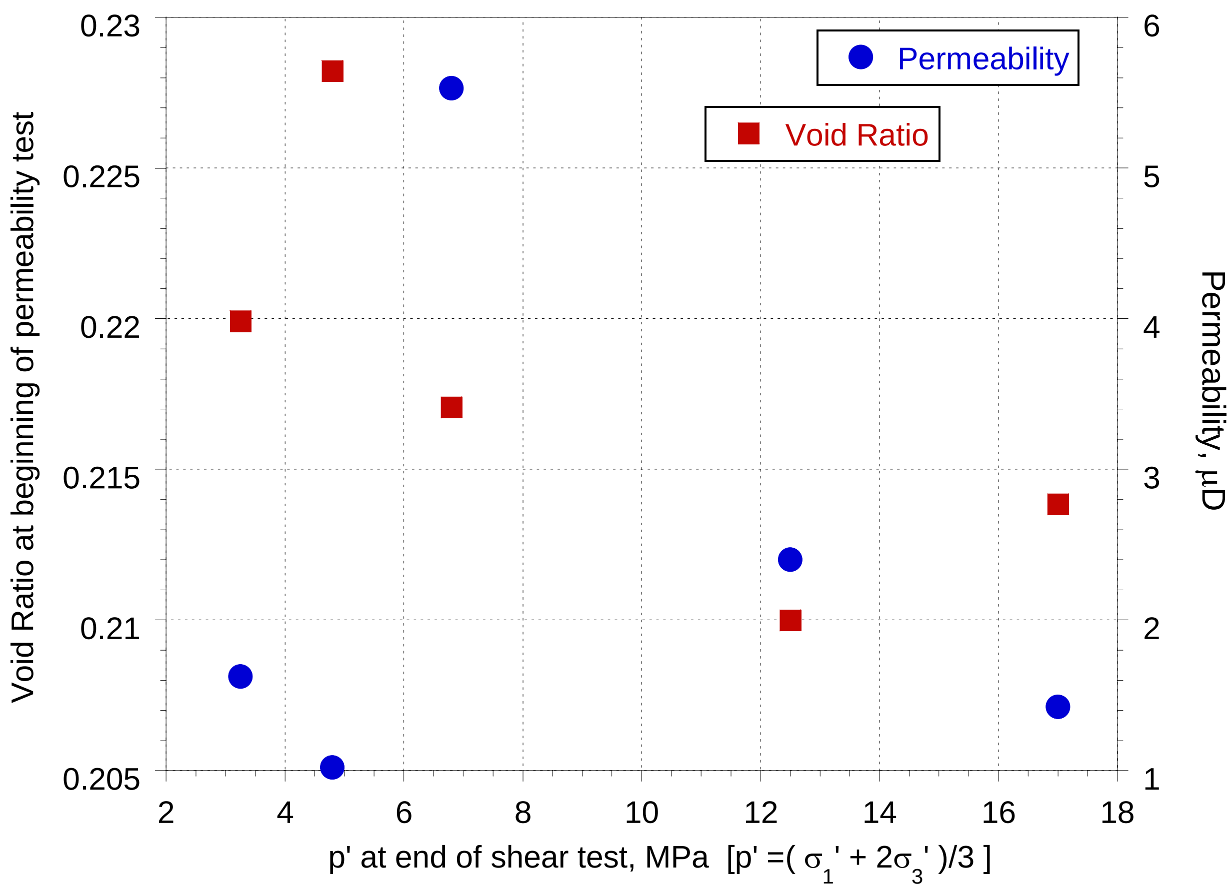


Figure 101. Variation of effective permeability to water with void ratio and mean effective confining stress at end of triaxial shear test.