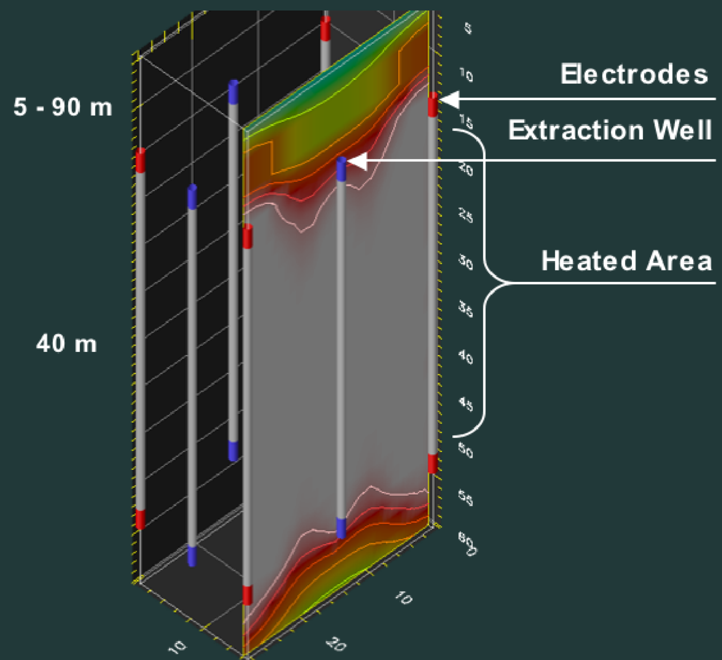
ET-DSP™

Poplar Creek Step 3 Final Report

Non-Confidential

E-T Energy Ltd.



Climate Change and Emissions Management Corporation .

Calgary, Alberta
December, 2013

Poplar Creek Step 3 Final Report Non-Confidential

Project ID #: G101061

Project Title: Commercial Demonstration of ET-DSP™ in the Athabasca Oil Sands

Project Advisor: Les Little

Project Completion Date: June 30 2013

Total Funds Received: $6,175,674

Total Holdback: $686,186

Prepared by:

Principal Investigator: Bruce McGee, E-T Energy Ltd.

Suite 410, 1210 8th Street SW

Calgary, AB T2R 1L3

Submission Date: December 18, 2013

Acronyms

AC	Alternating Current
AER	Alberta Energy Regulator
BOP	Blowout Preventer
BGS	Below Ground Surface
bbl	Barrel
bbl/d	Barrels per Day
CAD	Chemical Abstract Service
CCEMC	Climate Change and Emissions Management Corporation
CDN	Canadian Dollar Currency
cP	Centipoise
CT	Current Transducer
CWE	Cold Water Equivalent
d	Days
ET-DSP™	Electro-Thermal Dynamic Stripping Process™
ERCB	Energy Resources Conservation Board
ERH	Electrical Resistive Heating
EOR	Energy Oil Ratio kWh/bbl
E-Wells	Electrode Wells
FWKO	Free Water Knockout Tank
k	Permeability
k_r	Relative Permeability
KPa	Kilopascals
kW	kilowatt
kWh	kilowatt-hour
L	Litre
m	Metre
mBGS	Meters Below Ground Surface
mD	Millidarcys
mm	Millimetre
MW	MegaWatt
OB-Wells	Observation wells
O&M	Operations & Maintenance
PCP	Progressive Cavity Pump
PDS	Power Delivery System
PPM	Parts Per Million
RF	Radio Frequency
SAGD	Steam Assisted Gravity Drainage
SP	Spontaneous Potential [log]
SS	Stainless Steel
TD	Total Depth

TDCM	Time Distributed Control Module
TDS	Time Distributed Control Module
VRR	Voidage replacement ratio
WCS	Water Circulation System
X-Wells	Production Wells

Subcripts

e	electrode
g	gas
I	Imaginary
m	month
o	oil
R	Real
t	total
w	water

Equation Symbols

λ_c	Thermal Conductivity of the Chemical [W/m/˚C]
λ_w	Thermal Conductivity of the Water [W/m/˚C]
λ_r	Thermal Conductivity of the Rock [W/m/˚C]
λ_{ob}	Thermal Conductivity of the Overburden [W/m/˚C]
λ_{ub}	Thermal Conductivity of the Underburden [W/m/˚C]
ρ	Electrical Resistivity [Ωm]
σ_w	Electrical Conductivity of the Water [S/m]
A_{gw}	Electrical Resistivity [Ωm]
h_e	Electrode Length [m]
L_e	Electrode Length [m]
P_i	Initial Pressure [kPa]
R_e	Electrode Resistance
S_c	Chemical Saturation [-]
S_g	Gas Saturation [-]
S_w	Electrical Resistivity [Ωm]
T_i	Initial Temperature [˚C]
a	Cementation Factor in Archie's Law [-]
a_I	Fit Parameters in a Cubic Fit of Temperature [-]

Executive Summary

E-T Energy Ltd. (E-T Energy) pursuant to a co-funding arrangement with Climate Change and Emissions Management Corporation (CCEMC) completed a field test of the Electro-Thermal Dynamic Stripping Process™ (ET-DSP™), which uses electricity to heat the bitumen in-situ so it can be mobilized and extracted. The Step 3 Field Test consisted of 43 wells drilled into an area of approximately 0.8 acres at a testing site located approximately 3.5 km North of Fort McMurray.

The *Heating Phase* began on January 31, 2012, when power delivery to all 69 electrodes within the 23 electrode wells commenced. Heating continued without production for almost 5 months until June 25, 2012, when the first production well (X-03) was started. Despite some technical issues, heating continued until March 31, 2013, when power to the electrodes was shut off. Production continued until early May 2013 when the producer wells were shut off. Pressure and temperature monitoring continued to the end of June 2013.

Overall 4,831 megawatt-hours (MWh) of electrical energy, or approximately 80% of the design energy input, were delivered to the middle and lower electrodes. Energy input of 1,010 MWh was delivered to the upper electrodes before they were shut off due to the lower quality reservoir at this depth. The average formation temperature in the middle and lower zones increased from approximately 5˚C to 65˚C. Peak temperatures in some of the observation and production wells reached over 80˚C.

The expectations of Step 3 were to achieve a recovery factor of 40% and an Energy Oil Ratio (EOR) of less than 100 kilowatt-hours per barrel (kWh/bbl) from a high quality reservoir. An EOR of 100 kWh/bbl would result in CO_2 emissions of approximately 37 kilograms per barrel based on sourcing power from a high efficiency natural gas-fired power plant, which is roughly 47% less than the emissions resulting from bitumen production using steam assisted gravity drainage (SAGD).

The existence of a top water and associated lean zone within the reservoir where the extraction wells were also completed required that a new set of expectations for Step 3 performance be established. The performance of ET-DSP™ within the Step 3 reservoir exceeded E-T Energy's revised expectations for production and energy use.

E-T Energy plans to continue testing ET-DSP™ process on its leases and has received approval from the Alberta Energy Regulator to expand its field test site at a location north west of its current location.

Introduction

This report has been prepared by E-T Energy pursuant to a co-funding arrangement provided by the Climate Change and Emissions Management Corporation (CCEMC). The purpose of this report is to provide details on the technical outcomes of the project, provide a summary of the project performance and to provide recommendations for further research. Figure 1 shows the location of the field test site and Figure 2 shows the Step 3 well field layout.

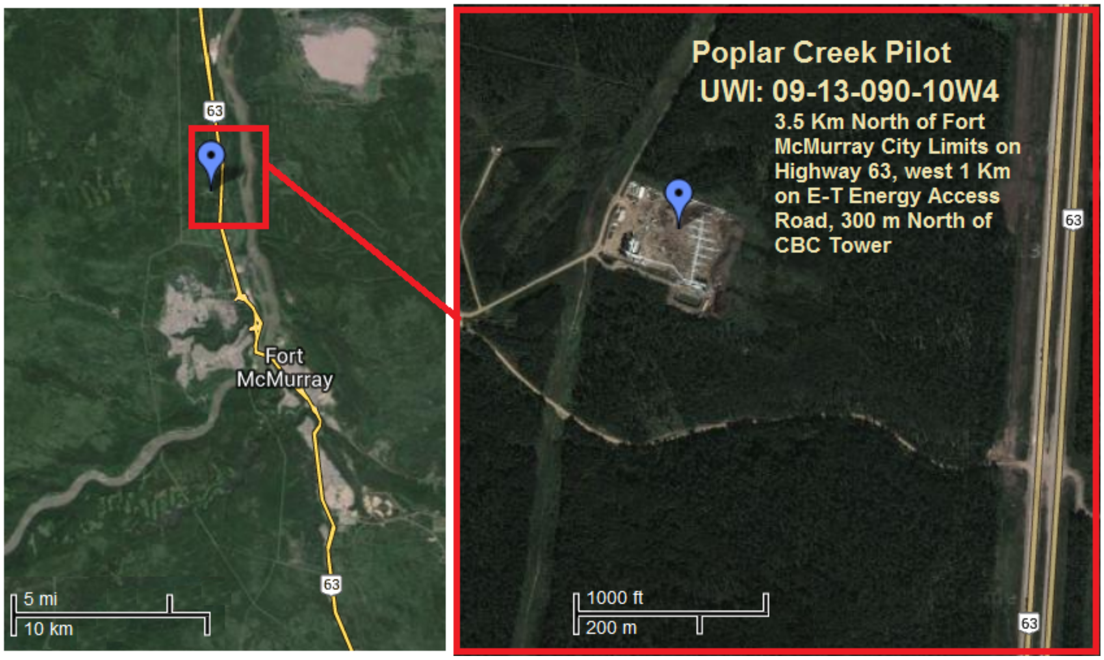


Figure 1: Field Test Site Location

ET-DSP™ Background

Electro-thermal heating of the Alberta oil sands has been studied since the early 1970's *[1], [2], [3].* ET-DSP™ uses electricity to heat the bitumen in-situ so it can be mobilized and extracted. Low-frequency electrical current is forced to flow through the continuous connate water phase that wets the sand grains from electrodes placed within the bitumen formation[1]. As current passes through the connate water, electrical energy is converted to heat proportionally to the ohmic resistance of the reservoir. The increase in temperature of the connate water in turn heats and mobilizes the bitumen that surrounds it.

[1] The distance between electrodes is 16 m.

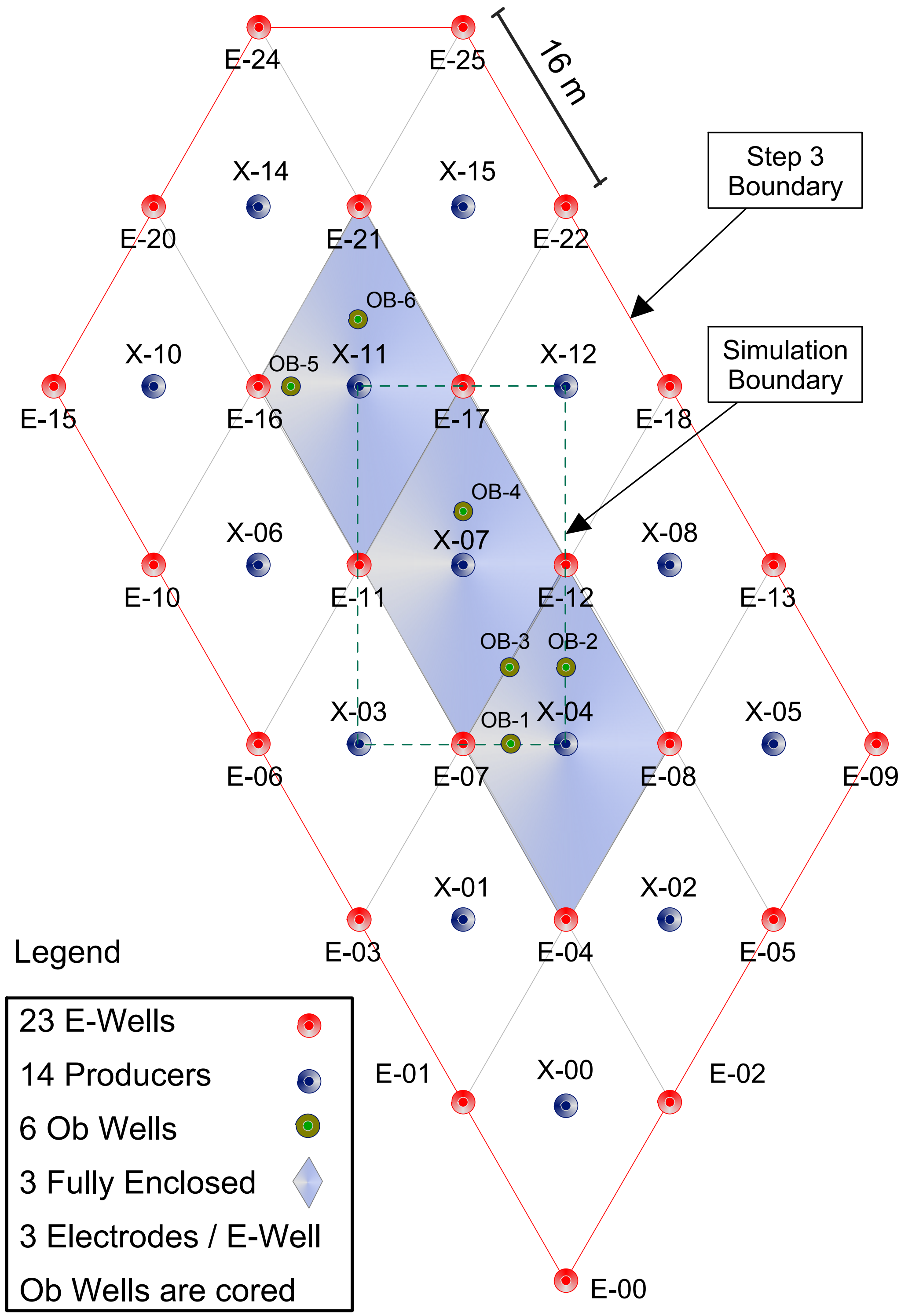


Figure 2: Step 3 Well Field Layout

ET-DSP™ is a specialized electrical heating technology used extensively in the environmental industry to remediate contaminated soil and groundwater *[4], [5].*

After nearly ten years of use in the environmental industry, it has been adapted for the thermal stimulation and recovery of bitumen from oil sand reservoirs. A proof of concept field pilot in the McMurray formation was conducted in 2007 and was deemed to be successful *[6]*. Using a tight well spacing, the pilot demonstrated the effective recovery of approximately 75% of the original bitumen in place. Sand production was minimal and the produced bitumen was emulsion free *[7].*

E-T Energy has the exclusive license to use the technology for applications in the recovery of heavy oil and bitumen. E-T Energy believes ET-DSP™ has the potential to extract bitumen on a commercial scale with substantially less impact on the environment, including a significant reduction in carbon dioxide (CO_2) emissions, when compared to other commercial bitumen production methods.

Objectives

The Step 3 Test was the third and largest field test conducted by E-T Energy using ET-DSP™. The objectives of the test were to:

1. Gather data and information on bitumen heating and production rates, energy intensity, CO_2 emissions,
2. Test equipment reliability and integrity, optimize electrode operation and
3. Provide insights for larger scale development.

Project Components

Pursuant to its contractual arrangements with Total E&P Canada Ltd. (Total E&P) the Step 3 Field Test consisted of 43 wells drilled into an area of approximately 0.8 acres. Three different well completions consisted of:

- 23 electrode wells (with three electrodes vertically stacked in each wellbore),
- 14 production wells (completed with progressive cavity pumps), and
- 6 observation wells.

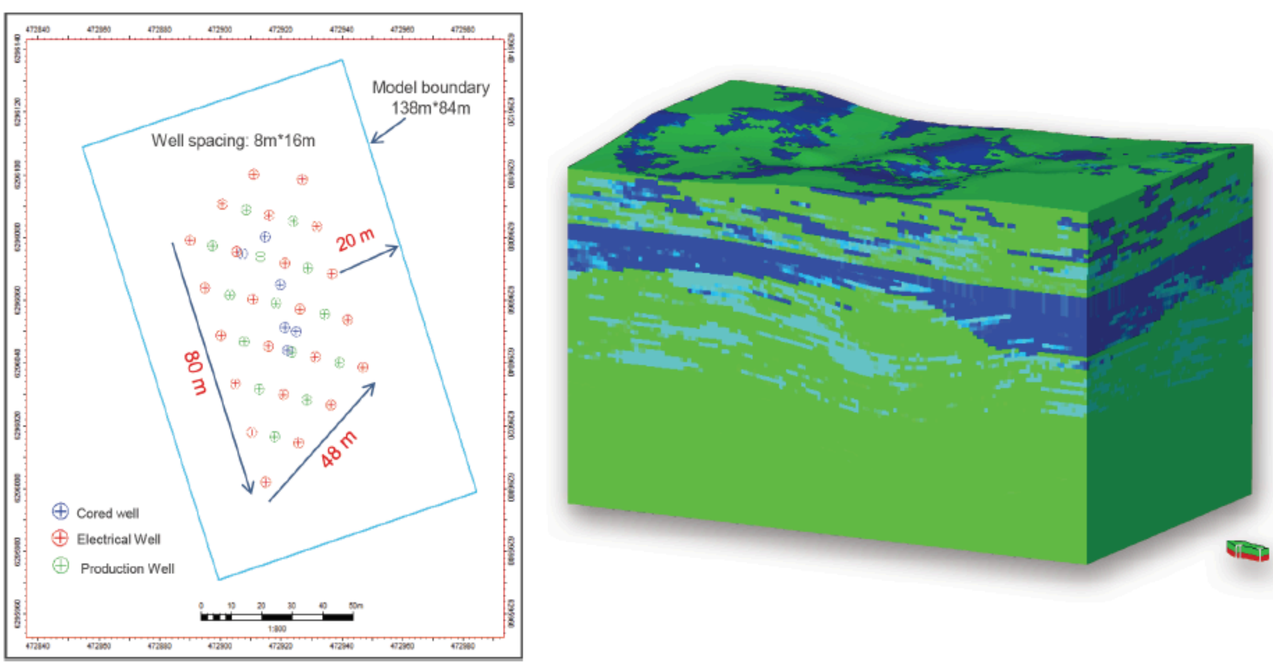
Step 3 was the first test in which a sufficient number of wells could be patterned such that certain *key* production wells were totally surrounded by other production and electrode wells. The results from key producing wells were expected to be more indicative of the results from a large-scale commercial project. By virtue of the greater size of the well field in a commercial situation, most of the producing wells would be fully surrounded by other producing and electrode wells.

Operations

The *Heating Phase* began on January 31, 2012, when power delivery to all 69 electrodes within the 23 electrode wells commenced. Heating continued without production for almost 5 months until June 25, 2012, when the first production well (X-03) was started. Despite some technical issues, heating continued until March 31, 2013, when power to the electrodes was shut off. Production continued until early May 2013 when the producer wells were shut off. Pressure and temperature monitoring continued to the end of June 2013.

Geologic and Reservoir Conditions

During the *Heating Phase*, a top water and lean zone was identified in the top third of the anticipated reservoir as indicated in the reservoir geo-model shown in Figure 3 and the Dean-Stark analysis results shown in Figure 4. Operation of the upper layer of electrodes adjacent to this water zone was suspended given the limited benefit from heating. Unfortunately, the production wells were completed before the top water and lean zone was identified and as a result were screened through this zone. The presence of a water zone had a negative impact on the production from a reservoir.



E-T Energy Geomodel Developed by Total E&P Canada

Figure 3: Reservoir Geomodel

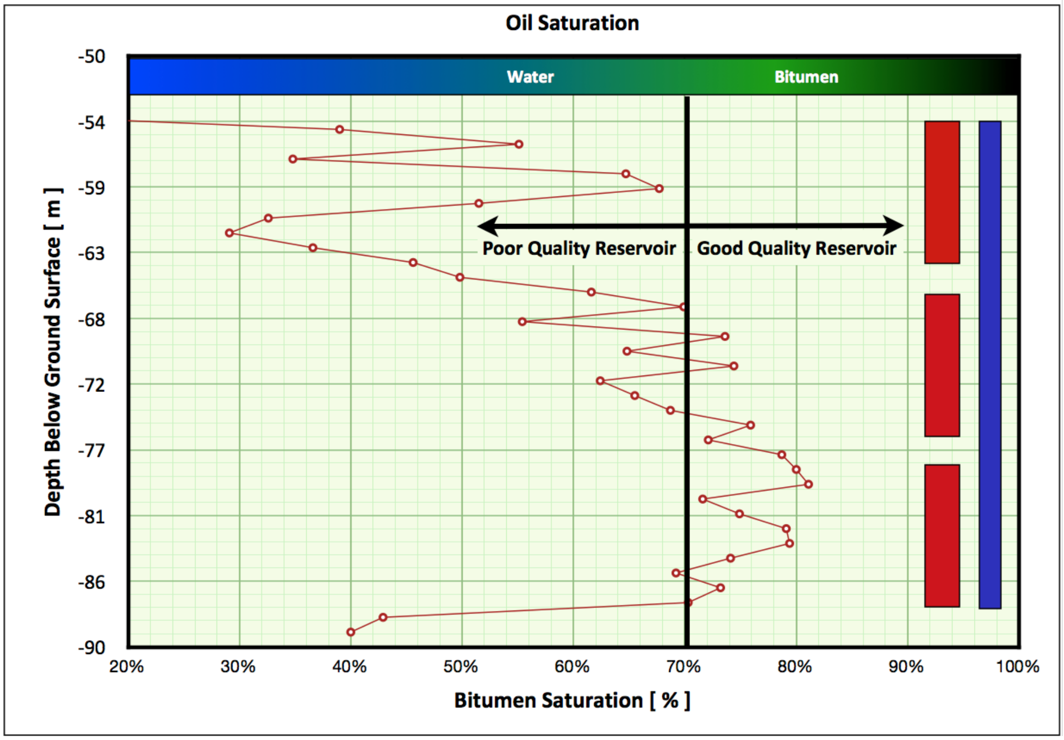


Figure 4: Dean Stark Analysis

The bitumen saturation varies throughout the pay zone as indicated by results from the Dean Stark analysis performed on six cores obtained from the Step 3 field test. The upper half to one-third of the pay has bitumen saturations consistent with a lean or poor quality reservoir. The lower pay zone is good quality reservoir and is consistent with geology experienced from other field tests performed at Poplar Creek. For convenience, the figure shows the relative location of the electrodes (red) and completed interval for the production wells (blue).

Energy Input

Referring to Figure 5 and Figure 6, overall 4,831 MWh of electrical energy, or approximately 80% of the design energy input, were delivered to the middle and lower electrodes. Energy input of 1,010 MWh was delivered to the upper electrodes before they were shut off due to the lower quality reservoir at this depth.

Later in the heating phase, several middle and lower electrodes electrically short-circuited with each other in some of the electrode wells. Consequently, these electrodes were not able to deliver power at the target rate, which slowed the reservoir heating and restricted the ability to fully control the power to individual electrodes.

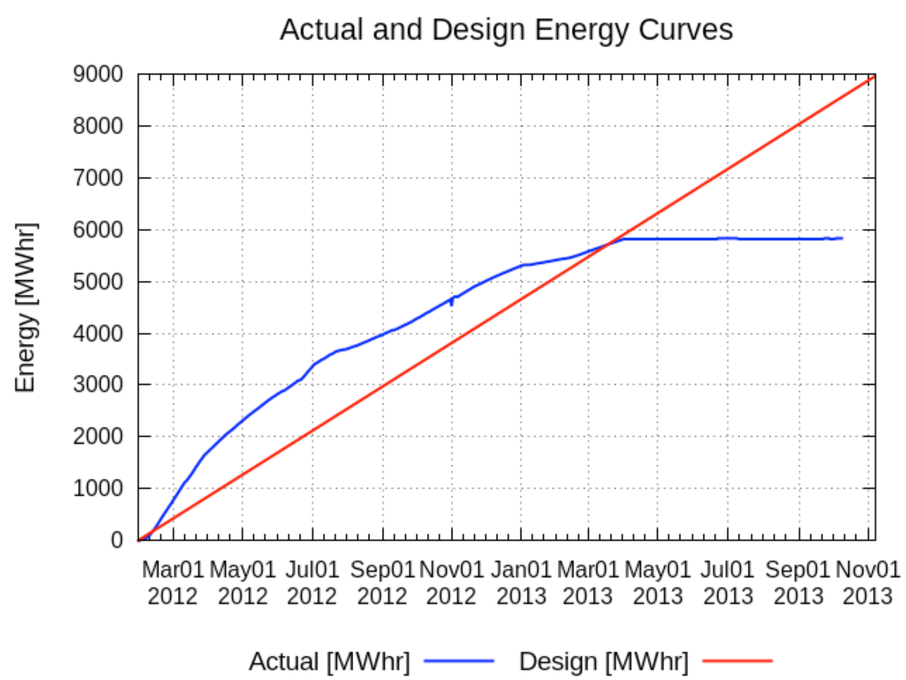


Figure 5: Total Energy Summary

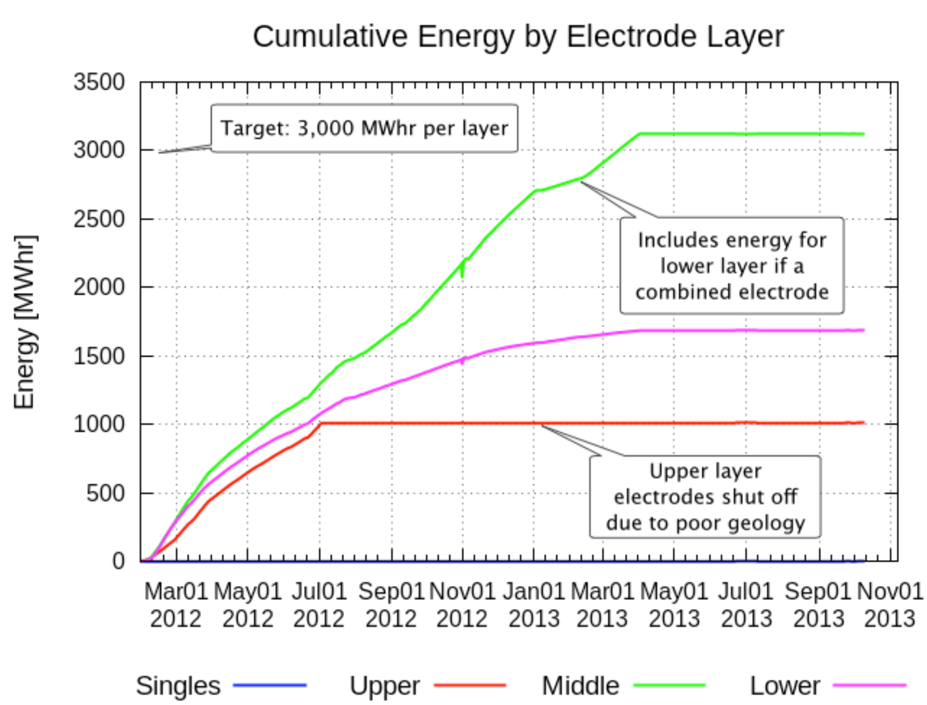


Figure 6: Energy Summary by Layer

Short-circuited electrodes behaved as a single electrode within a well bore. The middle and lower layer cumulative energy shown in Figure 6 is an approximation of the allocation of the energy for each layer, which was generally allocated to the middle electrode, if the electrodes were shorted together. E-T Energy is considering extracting electrodes and wires to further evaluate this problem and are in discussions with experienced down-hole wire manufacturers.

Temperature Distribution

The average formation temperature in the middle and lower zones increased from approximately 5˚C to 65˚C as indicated in Figure 7. Peak temperatures in some of the observation and production wells reached over 80˚C. As expected, the hottest producer wells also had some of the best production rates. The temperature distribution varies over the site because of changes in operational activities and variable geology.

Figure 8 shows the temperature distribution in the upper layer electrodes where the electrodes were turned off on July 4, 2012 because of the presence of a water-sand. The temperatures are much cooler there. This demonstrates an important feature of ET-DSP™ process, which is the flexibility to control heating to target zones within the reservoir. On the other hand, completion of a steam injection well into a water-sand would like result in the abandonment of that well.

Production

Production of emulsion ranged from 6-25 bpd in the period of September 2012 to May 2013, and continued to increase along with temperature increases. A total of 3,910 bbls of bitumen was produced and sold from the Step 3 Test as indicated in Figure 9, the most bitumen produced from any single E-T Energy field test to date.

The project was shut down, possibly prematurely, due to financial constraints. The benefits of continuing production, such as achieving a higher daily production rate or improving the recovery factor, would have been challenged by the top-water lean zone as well as possible channelling in the reservoir. *It is important to note that at the time the project was shutdown, average reservoir temperatures were increasing at approximately 5˚C per month and production rates continued to increase along with the rise in temperature. Furthermore, reservoir engineering calculations indicate that production from the extraction wells would have consisted almost entirely of water, given the overlying lean reservoir in which the extraction wells were completed.*

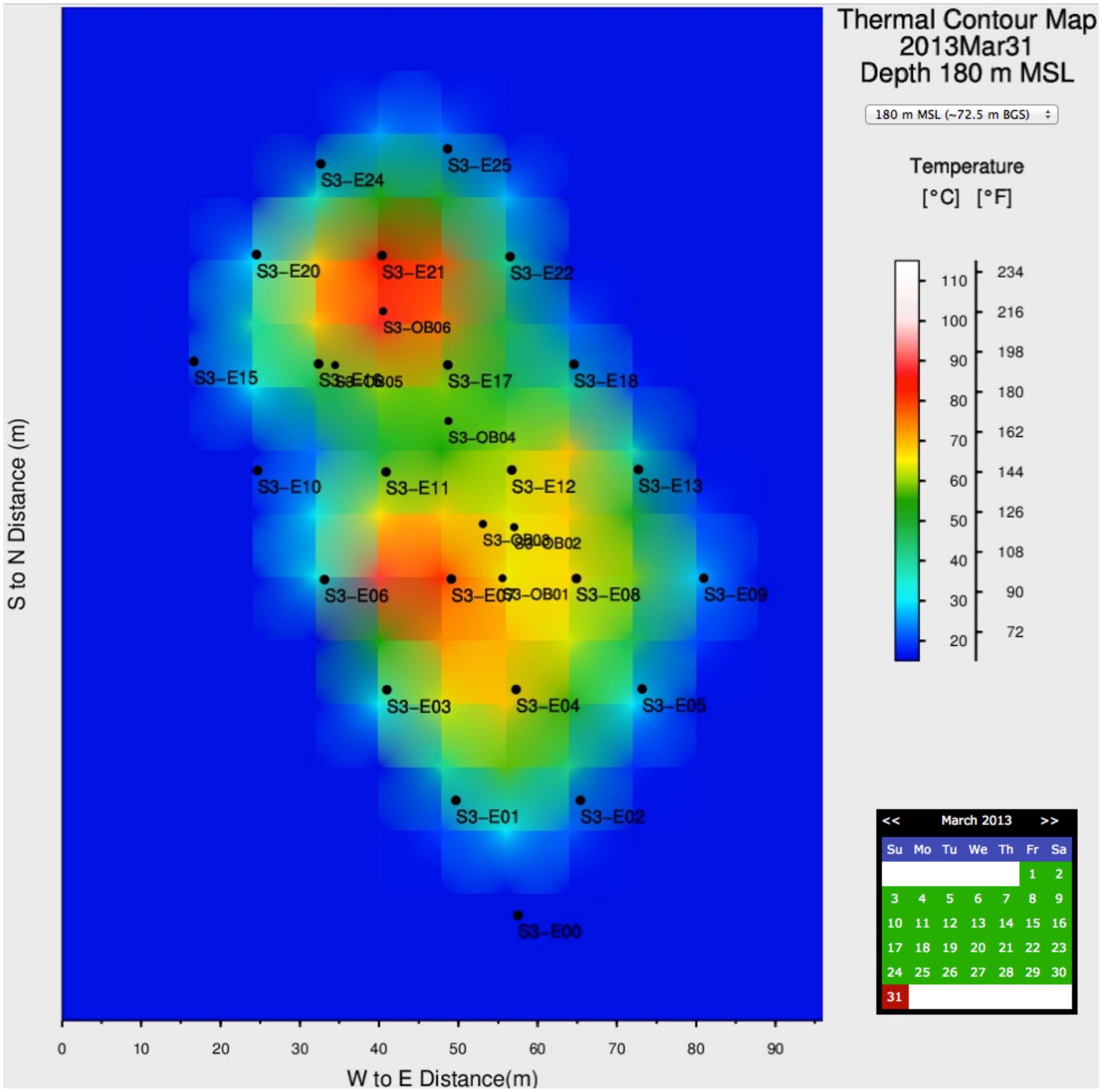


Figure 7: Temperature distribution at 72.5 m BGS

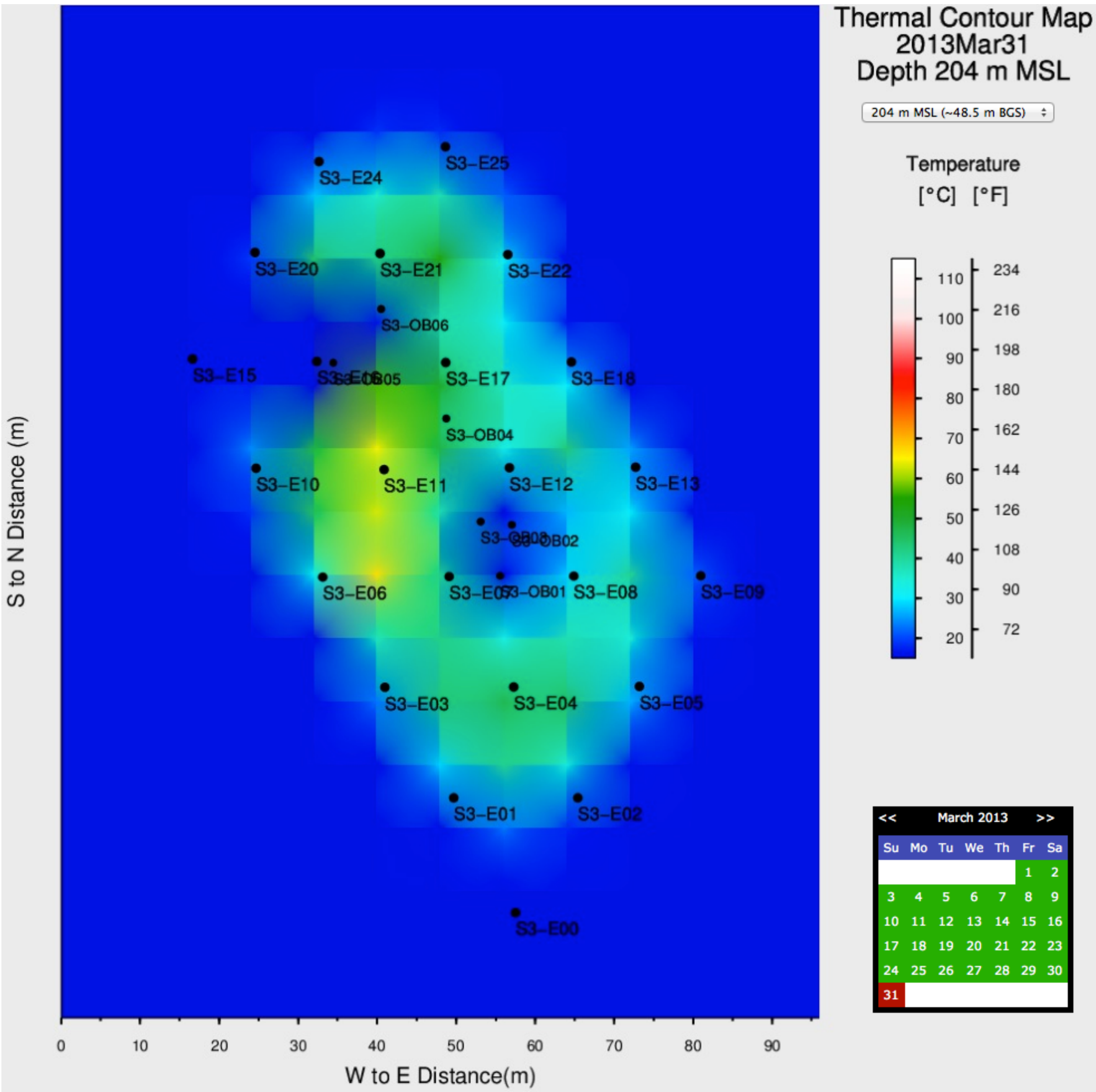


Figure 8: Temperature distribution at 48.5 m BGS

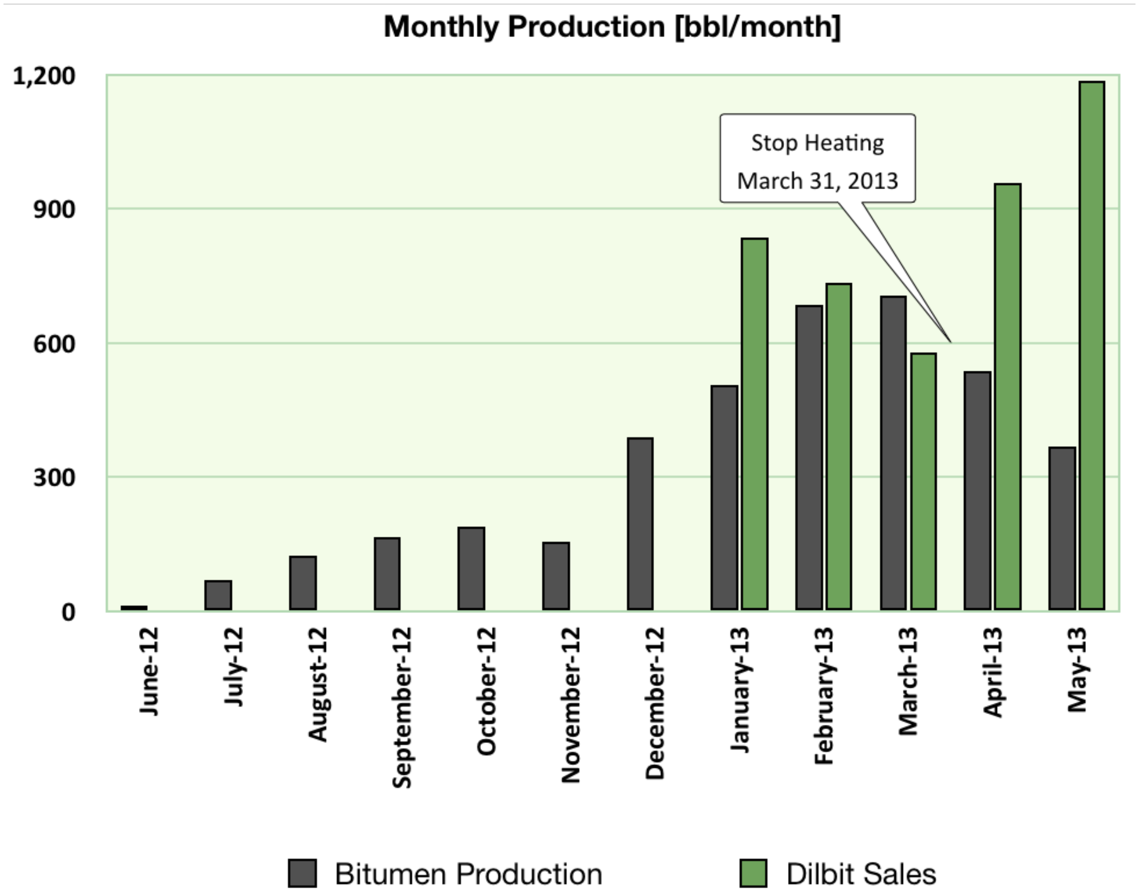


Figure 9: Monthly Production and Sales

Project Achievements

Several achievements were realized from the Step 3 Test. These include:

1. No on-site CO_2 emissions,
2. Demonstration of the ability to *selectively* heat, mobilize and produce bitumen using electro-thermal energy in a challenging geology compromised by a water sand and lean zone at the top of the reservoir,
3. Production of sand free bitumen in volumes that exceeded revised expectations based on the nature of the geology,
4. Successful in the commissioning, start up and operation of the largest ET-DSP™ and electro-thermal field test undertaken to date,

5. Greater than 95% operational up-time with the power delivery systems, other surface equipment and facilities, and continuous collection of temperature, production volumes, and energy related data,
6. Operate the project safely with zero lost time hours, and
7. Market produced bitumen to both the pipeline (meeting strict pipeline fluid specifications) and rail systems without penalty.

The expectations of Step 3 were to achieve a recovery factor of 40% and an EOR of less than 100 kWh/bbl from a high quality reservoir. An EOR of 100 kWh/bbl would result in CO_2 emissions of approximately 37 kilograms per barrel based on sourcing power from a high efficiency natural gas-fired power plant, which is roughly 47% less than the emissions resulting from bitumen production using steam assisted gravity drainage (SAGD).

The existence of a top water and associated lean zone within the reservoir where the extraction wells were also completed, as shown by the Dean Stark data for Step 3 summarized in Figure 4, required that a new set of expectations for Step 3 performance be established.

Based on the finding of significantly different geology than anticipated, E-T Energy performed an internal reservoir engineering simulation study to evaluate production and performance expectations from the reservoir. The reservoir specifications are largely adapted from the Dean Stark analysis of six core wells as described in Figure 4.

Operations Summary

Step 3 operations are summarized in Figure 10. These operations are defined by two distinguishing events; heating of the Upper, Middle, and Lower layers (Phase I)[2], and heating of just the Middle and Lower layers (Phase II) of reservoir. Step 3 operations started heating on January 31, 2012. With the discovery of a water zone in the top third of the reservoir, power to the Upper electrodes was stopped on July 4, 2012, thus defining Phase I of operations.

Production began at X-05 on June 25, 2012, approximately 146 days after the commencement of heating. Phase II heating operations consisted of heating the Middle and Lower electrodes for an additional 270 days. Power to the electrodes was terminated on March 31, 2013. Production from the extraction wells continued to May 11, 2013 and data monitoring continued to June 30, 2013.

[2] Heating operations were limited to half days during electrical commissioning of the surface facilities and electrical system for approximately 85 days.

Simulation Study

The E-T Energy simulation study results are summarized in Figure 11 where expectations for production performance and energy requirements for using ET-DSP in the reservoir encountered at Step 3 are tabulated. The cumulative production per well estimated from the simulation was 4.14 m^3 and the energy oil ratio (EOR) is 13,238 kWh/bbl. The actual performance of the Step 3 field test significantly exceeded the simulation estimate suggesting that reservoir drive mechanisms such as foamy oil are not incorporated in the simulation. The actual cumulative production per well was 44.40 m^3 and the energy oil ratio (EOR) was 1,236 kWh/bbl, or equivalent steam oil ratio (SOR) of 9.23.

The results from the simulation study provided the following insights;

1. The performance of ET-DSP™ within the Step 3 reservoir exceeded our revised expectations for production and energy use,
2. Unlike steam injection technologies, it was possible to focus the heating into just the higher quality zones within the reservoir and provided the opportunity for improved energy efficiency[3], and
3. The observed production of bitumen from Step 3 was foamy in nature, as exemplified in Figure 12, and at higher rates than expected, suggesting a drive mechanism related to the associated gas that was not be captured in the numerical model[4]. Furthermore the results of a chemical additive surfactant used in the later stages of the test program suggest that this may also have enhanced bitumen production.

Performance

On an individual well basis, the highest recovery factor achieved was 741 bbls of bitumen from X-03. The equivalent recovery factor is 9.3% of bitumen in place. Well X-03's share of the power injected into the electrode wells surrounding it was approximately 311 MWh for the middle and lower electrodes, which results in an EOR of 420 kWh/bbl or SOR of 3.14.

Not withstanding the impact of poor reservoir quality on the objectives set out for the Step 3 field test, several of the electrodes were compromised mid-way through the life of the project. At the time of writing the reason for electrode failure is still under review. The next step will be to examine compromised electrodes and engineer an appropriate solution for improving electrode reliability.

[3] Under normal circumstances an extraction well would not be completed in the water zone. However, the geological model of the Step 3 reservoir was not available until after the completion of the wells.
[4] More investigation into the foamy oil drive mechanism is recommended.

Step 3 Operations Summary		
Phase I (All Electrodes On)		
Begin heating to electrodes	Jan 31, 2012	
Begin bitumen extraction	June 25, 2012	
Days of heating prior to extraction	146 days	
Turn off the Upper electrodes	July 4, 2012	
Days of heating to all electrodes	155 days	
Cumulative energy to all electrodes	3,400,000	[kW•hr] after 155 days
Cumulative energy to Upper electrodes	1,010,000	[kW•hr] after 155 days
Average electrode power to July 4, 2012	13.25	[kW]
Phase II (Upper Electrodes Off)		
Days of heating	270 days	
Cumulative energy during Phase II	2,441,000	[kW•hr] after 270 days
Average electrode power	8.19	[kW]
Shut off power to all the electrodes	March 31, 2013	
Step 3 Totals		
Days of operations	425 days	
Stop bitumen extraction	May 11, 2013	
Terminate data monitoring	June 30, 2013	
Cumulative bitumen extraction	621.64	[m^3]
Cumulative energy to Middle & Lower electrodes	4,831,000	[kW•hr] after 425 days
Cumulative energy to all electrodes	5,841,000	[kW•hr] after 425 days

Figure 10: Step 3 Operations Summary

Step 3 operations commenced with heating on January 31, 2012. With the discovery of a water zone in the top third of the reservoir, power to the Upper electrodes was stopped on July 4, 2012, thus defining Phase I of operations. Production began at X-05 on June 25, 2012, approximately 146 days after the commencement of heating. Phase II heating operations consisted of heating the Middle and Lower electrodes for an additional 270 days. Power to the electrodes was terminated on March 31, 2013. Production from the extraction wells continued to May 11, 2013 and data monitoring continued to June 30, 2013.

Numerical Evaluation of Production Performance

Parameter	Simulation Results	Field Test Results	Units
Phase I (All Electrodes On)			
Phase I Electrical Energy	1,065,243,000		[GJ]
	295,901	3,334,194	[kW•hr]
Duration	155 days	155 days	
Average Electrode Power	13.26	13.25	[kW]
Current Scaling Factor	1.00		
Phase II (Upper Electrodes Off)			
Phase I + II Electrical Energy	1,926,802,000		[GJ]
Phase II Electrical Energy	861,559,000		[GJ]
	239,322	5,802,316	[kW•hr]
Duration	270 days	270 days	
Average Electrode Power	8.21	8.19	[kW]
Current Scaling Factor	1.00		
Cumulative production per well	**4.14**	**44.40**	**[m^3]**
Step 3 EOR	**13,237.55**	**1,235.55**	**[kW•hr/bbl]**
Phase II EOR	**13,237.55**	**1,235.55**	**[kW•hr/bbl]**
Phase II SOR_e	**98.84**	**9.23**	**[-]**

Figure 11: Simulation Results

The simulation results indicate that the presence of low quality reservoir in the upper layer and the completion of the extraction well in that layer will result in poor production performance. The actual production from Step 3 operations is greater than that estimated from the simulation study and the equivalent SOR is proportionately less.

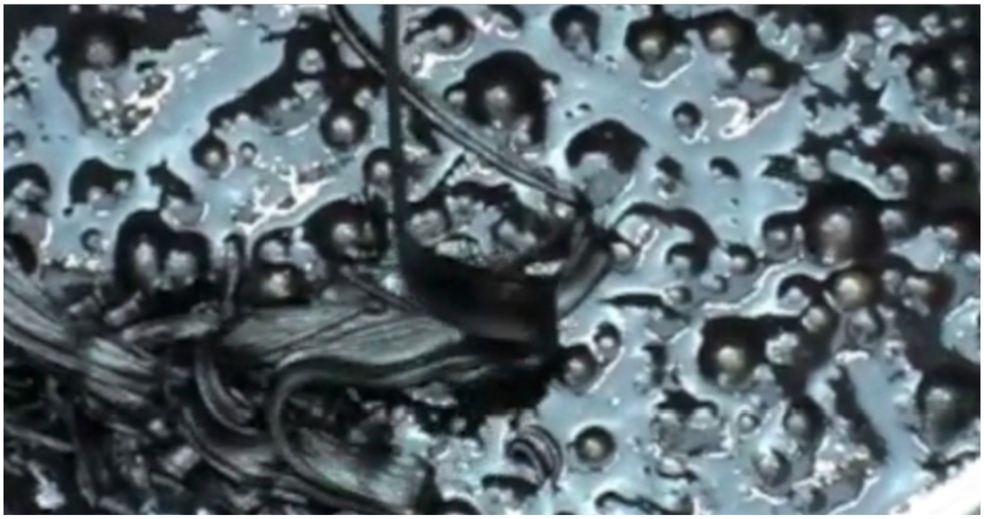


Figure 12: Foamy Oil

The bitumen produced from the extraction wells was full of bubbles and foamy in nature. This is caused by the associated methane gas coming out of solution as a result of elevated temperature and low pressure around the wellbore. If the bubbles are dispersed in the reservoir, as we believe they are, then the effective volume of the foamy fluid can be as high as three times the volume of the liquid bitumen. This reasonably assumes a solution gas oil ratio that has a volume of dissolved gas equivalent to 1 m^3/m^3. The change in effective density provides tremendous drive energy for the bitumen.

Greenhouse Gas Emissions

Greenhouse gas emissions (GHGs) were estimated based on the production achieved and are presented in Table 1. The table also provides estimates of the GHGs expected from a Step 3 Test that achieved a 40% recovery (*Step 3: Projected Emissions)*, a commercial-scale ET-DSP™ project, and a comparison to emissions that could be expected from a well performing SAGD project.

As noted in Table 1, the emissions per barrel from the X-03 well were ~1/3 the emissions per barrel of the overall project. The GHGs estimated for the commercial-scale application of ET-DSP™ are based on the numerical simulation that history matched the results from the Proof of Concept Test *[11]* and then extrapolated those results to a large-scale implementation.

Table 1: Step 3 and Commercial-Scale Greenhouse Gas Emissions

Component	Energy Oil Ratio (EOR)	Steam Oil Ratio or Equivalent	Energy Source Emission Rate	CO_2 Emissions per Barrel
	kWh/bbl	SOR or SOR_e	kg CO_2/kWh	kg CO_2/bbl
Step 3: Overall Project[3]	1,236[1]	9.2	0.73[2]	900
Step 3: Well X-03	420[3]	3.1	0.73[2]	310
ET-DSP™ Commercial Project	75[4]	0.6	0.37[5]	28
	100[6]	0.7	0.37[5]	37
SAGD Project	NA	3.0	NA	69[7]

Notes
1. *Step 3 Overall Project* production was 3,910 bbls and 4,831,000 kWh of electrical energy to middle and lower electrodes.
2. Table A13-10, page 75, National Inventory Report, *Greenhouse Gas Sources and Sinks in Canada*, The Canadian Government's Submission to the Un Framework Convention on Climate Change, Part 3.
3. *Step 3 Well X-03* production was 741 bbls and 331,000 kWh of electrical energy to middle and lower electrodes.
4. ET-DSP™ Commercial EOR rate developed in *ET-DSP™ Reservoir Simulation Study*, October 2008.
5. *Life-Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System*, National Renewable Energy Laboratory, US Dept. of Energy, September 2000.
6. Upper range of ET-DSP™ Commercial EOR rate based on adding a 33% contingency to rates developed in *ET-DSP™ Reservoir Simulation Study*, October 2008.
7. Table A-8, IHS CERA Special Report - Oilsands, Greenhouse Gases, and US Oil Supply, 2010

Lessons Learned

E-T Energy is encouraged by the ability to deliver power to the reservoir and the temperature response achieved. The results from the Step 3 Field Test provide invaluable learnings towards commercializing ET-DSP™ for the production of bitumen from the oil sands. These include:

1. **Production Drive Mechanisms**: The production drive mechanisms available from a low-pressure thermal recovery process like ET-DSP™ are different than with high-pressure steam injection processes. With ET-DSP™, the pressure and temperature in the reservoir (especially near the extraction wells) are such as to enable the evolution of associated gas to form bubbles within the bitumen. This creates a much lower density fluid, much like foamy oil, that drives the fluid in the reservoir towards the extraction wells for production. Other drive mechanisms are simple gravity drainage of the fluids away from the electrodes (a source of pressure due to hydrostatic injection of water into the electrodes) towards the extraction wells (a pressure sink), and minor water flooding from the electrodes.

2. **Operation of the extraction well**: Ideally, the extraction wells should begin operations when the temperature in the reservoir is hot enough to produce mobilized bitumen. There is a trade-off. The sooner production from the extraction wells can begin the sooner convective heat transfer in the reservoir can be achieved. This is at the expense of producing too soon where cold production is not effective. A method to heat the extraction wells during initial heating of the reservoir has been tested by E-T Energy in previous field tests and found to be helpful. This approach should be adopted for commercial operations.

Next Steps

E-T Energy plans to continue testing ET-DSP™ process on its leases and has received approval from the Alberta Energy Regulator to expand its field test site at a location north west of its current location. Core testing in the area suggests the new site has a better quality reservoir than found at the Step 3 location. Additional core wells will be completed to confirm geologic conditions before committing to the new field test site. Future investigations planned with additional testing include:

1. **Extensive reservoir modelling**: More numerical simulation work needs to be done to quantify the production drive mechanisms as well as optimizing the ET-DSP™ process for the production of bitumen and heavy oil. The reservoir model will use data from the Step 3 Field Test to better understand reservoir production mechanisms, the influence of the top water and lean bitumen zone, heat transfer and losses, optimal production start up temperatures and the impact of water injection to establish preferential water pathways within the reservoir.
2. **Electrode reliability**: E-T Energy will undertake a thorough review of the sub-surface heating system including materials selection, installation techniques and operating procedures to improve electrode reliability. We believe this is the final technical hurdle to demonstrating commerciality of the process for bitumen recovery.

Costs

The total cost of the Step 3 Field Test was $20.6 million. CCEMC has financed $6.2 million of these costs to date and has retained a holdback of $686,186. E-T Energy earned revenue from this project from the sale of the bitumen produced and the sale of a data licence to Total E&P.

Revenues

Approximately 4,432 barrels of diluted bitumen (approximately 12% diluent) were sold, generating revenue of approximately $226,000, which was largely offset by transportation and diluent costs.

References

[1] F. S. Chute, R. E. Vermeulen, and M. R. Cervenan. Physical Modeling of the electrical heating of the Oil Sand Deposits. Technical Report AOSTRA Agrement No. 31, Applied Electromagnetics Group at the University of Alberta, 1978.

[2] F. S. Chute, R. E. Vermeulen, and M. R. Cervenan. Physical Modeling of the electrical heating of the Oil Sand and other Earth-Type and Biological Materials. *Canadian Electrical Engineering Journal*, 4(4): 19-28, 1979.

[3] Fred E. Vermeulen and F. Steve Chute. Electromagnetic Techniques in the In-Situ Recovery of Heavy Oils. *Journal of Microwave Power*, 18(1):15-29, 1983.

[4] Bruce C. W. McGee, Electro-Thermal Dynamic Stripping Process. *United States Patent No. 6,596,142*, July 22, 2003.

[5] Bruce C. W. McGee, Electro-Thermal Dynamic Stripping Process. *Canadian Intellectual Property Office Patent No. 2,341,937*, June 22, 2004.

[6] Bruce C. W. McGee and Fred E. Vermeulen. Electro-thermal pilot in the Athabasca Oil Sands: Theory versus performance. In Society of Petroleum Engineers, editor, *Canadian International Petroleum Conference/SPE Gas Technology Symposium 2008 Joint Conference*, number Paper 2008-209 in 59th Annual Canadian international Petroleum Conference, June 2008.

[7] Bruce C. W. McGee, Craig W. McDonald, and Les Little. Comparative Proof of Concept Results for Electro-Thermal Dynamic Stripping Process. In *2008 SPE International Thermal Operations and heavy Oil Symposium*, pages 4-12, Calgary, Alberta, Canada, October 20-23 2008. Society of Petroleum Engineers.

[8] Jan Czarnecki, Boryan Radoev, Laurier L. Schramm, and Radomir Slavchev. On the Nature of Athabasca Oil Sands. *Elsevier Advances in Colloid and interface Science*, Volume 114-115 (No. 4): 53-60, June 2005.

[9] D. A. W. Keith, J. R. MacGillivray, D. M. Wightman, D. D. Bell, T. Berezniuk, and H. Berhaane. *Resource Characterization of the McMurray/Wabiskaw Deposit in the Athabasca Central Region of Northeastern Alberta*. Alberta Research Council and Alberta Geological Survey, 1987.

[10] Schlumberger. MDT Modular Formation Dynamics Tester. http://www.slb.com/~/media/Files/evaluation/brochures/wireline_open_hole/insitu_fluid/mdt_brochure.pds, June 2002.

[11] Bruce C. W. McGee and Roger Donaldson, *ET-DSP™ Reservoir Simulation Study*, Submitted to McDaniel and Associates Consultants Ltd., October 2008

[12] Bruce c. W. McGee, Laura Sullivan, and Jonathan Backs. Analytic model for estimating the production of bitumen from the ET-DSP™ process with economics and comparisons to SAGD. *Canadian Energy Technology and Innovation,* 1(1):1 20, January 2012.

[13] Table A13-10, Year 2011, page 75, National Inventory Report, *Greenhouse Gas Sources and Sinks in Canada*, The Canadian Government's Submission to the UN Framework Convention on Climate Change, Part 3.

[14] *Life-Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System*, National Renewable Energy laboratory, US Dept. of Energy, September 2000.

[15] IHS CERA Special Report™, *Oil Sands, Greenhouse Gases, and US Oil Supply, Getting the Numbers Right*, Table A-8, 2010.