Ecosystem Impacts of Historical Shallow Gas Wells within the CFB Suffield National Wildlife Area

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2 February 2008

1.0 Purpose

This post site construction fieldwork project was completed to determine and document some of the short and long term impacts to the ecosystem of CFB Suffield with respect to shallow gas well development in the CFB Suffield National Wildlife Area (NWA), with consideration of both cattle grazing and fire. These results will then be combined with other reports assessing the impacts to the ecosystem of CFB Suffield in order to complete a suite of indicators that will be used to measure and monitor ecologically sustainable activities at CFB Suffield.

Policy and directives within the Department of National Defence (DND) require that the impacts of all activities on DND lands be minimized with respect to their effects on the ecosystem and environment. DND is specifically committed to "*Developing and implementing the concept of sustainable use of military training areas; planning and conducting military and non-military activities on Defence land and marine training areas such that adverse impacts are minimized and military training can occur without compromising the capacity for future training; and preserving biodiversity, in particular for species at risk*." (DND 2006). In order to optimize Range Standing Orders, management plans and training activities on the base and to minimize their potential and actual impacts, specific impacts on the range must first be realized, documented and understood.

2.0 Background

CFB Suffield

The ecosystem of CFB Suffield is comprised of the dry mixed grass sub-region of the Grasslands Natural Region of Alberta. The major plant species are spear grass (*Stipa spp.*) and blue gramma (*Bouteloua gracilis*). The topsoil layer is on average 10 cm or less thick with only 2 to 4 % organic matter. This ecosystem is slow growing, producing long lag periods between impact and restoration of the ecosystem and its components. The range is a local refuge for wildlife, and supports a number of species at risk including the burrowing owl and Ord's kangaroo rat.

Preservation of the health, biodiversity and abundance of mixed grass prairie is an important objective of CFB Suffield. The Base has selected the following as some of their valued ecosystem components and ecosystem goals: high native species diversity; high percent cover of native species; high bird, reptile and mammal diversity; preservation of all species at risk and their habitat; preservation of wetland function; minimal non-native species diversity and percent cover; preservation of healthy soil parameters for ensuring both the preservation of healthy mixed grass prairie. It is a result of these goals and valued ecosystem components that this study focuses on the vegetation and soil properties of CFB Suffield. Measurement of the percent cover and diversity of non-native vegetative species is vitally important to the monitoring and management programs of the Base, as non-native species invasion is the largest threat to mixed grass prairie following land development.

The major factors affecting the ecosystem at CFB Suffield include military training, military research, oil development, shallow gas development, deep gas development, cattle grazing, fire and natural climatic variation. These activities and stressors have been occurring for years, yet their individual and combined impacts are just beginning to be known and documented.

National Wildlife Area

Prior to 1941 the Suffield block was used for agriculture. In 1941 the Suffield block was purchased for the purpose of war research and became the chemical warfare proving grounds. In 1971 the land was commissioned to support training by the British Army. Today Canadian troops also train within CFB Suffield. A memorandum of understanding was signed between the Minister of National Defence and the Department of the Environment in 1992, setting aside the eastern portion (458 km^2) of the Base as a NWA. The NWA was officially designated in 2003.

In 1977 local cattle producers were allowed to graze within the Suffield Block (and the present NWA) due to drought conditions and lack of suitable grazing pastures. Grazing has continued within the Base since then, but was banned from the northeast section of the NWA due to concerns from Environment Canada regarding over-grazing in the sensitive middle sand hills. Military training has never been permitted within the NWA and presently the NWA is used as a permanent live military fire safety template in support of military training exercises and defence research trials. The southern section of the NWA is still used for grazing.

Study

Policy and directives within DND require that the impacts of all activities on DND lands be minimized with respect to their effects on the ecosystem and environment. In order to optimize Range Standing Orders, optimize training and activities on the Base and to minimize their potential and actual impacts, these impacts must first be realized and understood.

There have been few studies completed on the impacts of gas development at CFB Suffield: Impacts of Oil Development on Mixed Grass Prairie at CFB Suffield by Karen Anderson; 1262-1 (G3 Bio) Review of Proposed 2005 Oil and Gas Drilling Programs for CFB Suffield, January 2006; and finally Post Construction Vegetation Assessment of EnCana’s 16 Well per Section Pilot Project (AXYS 2005); The Suffield 2001 Shallow Gas Infill Drilling Program within the Riverbank and Middle Sandhill Zones of the National Wildlife Areas by AXYS Environmental Consulting Ltd, February 2005, Calgary Alberta; Comparison of Vegetation Parameters between On and Off-lease Areas after Minimal Disturbance Shallow Gas Development within the CFB Suffield National Wildlife Areas (Smith & Taylor 2007); and Assessment of Agronomic Species Invasion from Pipeline Right-of-way at CFB Suffield National Wildlife Area (Smith 2007). As well, an initial study was completed in 2005 (Rowland 2005) was used in part as a pilot study for this research, and thus the current report is a continuation of the 2005 study.

The NWA was selected for study as it has been void of training since 1972, thus the impacts found are a result of natural ecosystem stressors and cycles, as well as from gas development and cattle grazing. A time series was completed for the well sites and pipelines to determine the conditions at 22, 9 and 6 years following construction. Areas grazed by cattle were also assessed to determine its confounding impacts to the loamy soils within the NWA.

Soils

Soils of the northern part of the NWA are predominately Orthic Regosols and Rego Chernozems. The soils have developed on very coarse textured sand dunes and are highly susceptible to wind erosion. The A horizon is less than 5 cm thick and discontinuous. In the southern section of the NWA the soils are primarily Orthic Brown Chernzems, which have formed on medium to moderate textured glacial tills or sand dunes. The A horizons of these soils range up to 12 cm in thickness and have a lower probability of wind erosion than the soils in the northern section of the NWA.

Soil compaction and disturbance are a concern at CFB Suffield due to these sandy soils. There is a high probability of erosion following disturbance from well construction, or the servicing of the wells and pipelines. Soil disturbance ties into vegetation patterns and communities found within the Base, as the newly disturbed sites allow for quick and effective infestation of non-native species to the mixed grass prairie. Changes in soil density represent changes in soil compaction, which in turn are likely to allow the establishment of non-native species versus native species. Following along the same reasoning, the amount of bare soil was monitored.

Shear vane strength is an indicator of the amount of vegetative root establishment as well as soil structure, as the higher the soil shear vane strength, the higher the probability that the soil structure and horizons will not be disrupted following vehicle traversal. The depth of the topsoil and the organic content composition of the soil will provide information as to the probability of the soil having the required micro and macro nutrients required for native species establishment and growth. Measuring natural fluctuations in the amount of soil moisture available will assist in determining the predicted vegetation communities and the significance of compounding the effects of climate with any of the other training area impacts.

Petroleum Development

CFB Suffield has provided 2690 km^2, or all of its land area (manoeuvre training area, experimental proving grounds, NWA and Oil Access Area) to support oil and gas development. Future oil and gas development of the NWA is currently being debated and its' impacts discussed via an Environmental Assessment. The pace of gas development has increased significantly over the last few years and is expected to grow.

Oil and gas development consists of three phases: construction, operation and decommissioning. Besides the actual creation, development, monitoring and installation of the wells, there are also significant impacts resulting from connecting the wells to existing pipelines and from the creation and persistence of access routes to the well sites.

Potential impacts from oil and gas development include changes in vegetation species abundance and diversity, changes to soil parameters that determine vegetation communities, hydrocarbon contamination, erosion and changes in the landscape, encouragement of invasive plant species and impacts from fragmentation and linear corridors to all species. Note that the potential impacts of water and soil contamination will not be examined in this report.

Relevant guidelines and requirements for oil and gas development within Alberta include: IL 2002-1 Principles for Minimizing Surface Disturbance in Native Prairie and Parkland Areas (Alberta Environment); Petroleum Industry Activity in Native Prairie and Parkland Areas Guidelines for Minimizing Surface Disturbance Native Prairie Guidelines Working Group January 2002 (Sinton, 2001); Prairie Oil and Gas: A Lighter Footprint. (Alberta Environment).

Cattle Grazing

Cattle grazing begins yearly in June and ends at the end of October. Grazing is under the supervision of the Suffield Grazing Advisory Committee and Prairie Farm Rehabilitation Administration (PFRA). Potential grazing impacts include changes in vegetation species abundance and diversity, spread of invasive and non-native plant species and changes to the soil parameters that determine the vegetation communities. Note that the presence of these herbivores may be beneficial to the ecosystem of the Base, as the cattle will mimic some of the natural impacts/disturbances incurred when large populations of herbivores that once roamed and inhabited the prairies. The potential contamination of water will not be examined in this report.

Fire

Fire is a natural component of this ecosystem that retards succession, thereby maintaining a natural mixed grass prairie environment. Natural fire frequency has been reduced in Canada's prairies due to more effective fire fighting capabilities, natural fire breaks from roads and urban areas and from greater variation in land cover due to agricultural development and diversification. Determining the optimal fire frequency is currently a goal of CFB Suffield that will be assessed from the comparison of fire impacts to other factors impacting the ecosystem. Fire, whether it be naturally ignited from lightening, accidentally ignited from military training munitions or started as a prescribed burn, has the potential to change the species abundance and diversity, amount of litter and thereby soil temperatures and water evaporation rates, as well as the concentration of nutrients and organic matter required for re-vegetation. The impacts of fire from this study were removed by selecting sites that has had not recently been burnt (minimum 6 years).

Climatic Impacts

Natural fluctuations in climate will remain a strong contributor to ecosystem health, natural re-vegetation and both vegetation abundance and diversity. Natural cycles in wind and temperature patterns determine the duration of frost-free days, the monthly average temperature and the total amount of precipitation per month. These climatic fluctuations then in turn allow natural selection to encourage the presence and persistence of differing vegetation communities. This then extends to soil stability, the formation of blowouts and the creation and establishment of the optimal environment for invasive species. Measuring natural fluctuations in the amount of soil moisture available in the soil as well as the potential water retention capability of the soil will assist in determining the predicted vegetation communities and the significance of compounding the effects of climate with any of the other training area impacts. Accounting for climatic changes may also help explain both the present and historical vegetation communities.

3.0 Methodology

The CFB Suffield soil range map was used to determine the soil type within the NWA.

Ground investigations are based on assessing the following number of sites within the NWA per each of the following categories:

- Gas wells and pipelines installed in 2000 in the NWA with sandy soils (N = 15) (non-grazed areas);
- Gas wells and pipelines installed in 2000 in the NWA with loamy soils in grazed areas (N = 20);
- Gas wells installed in 1997 in the NWA with loamy soils in grazed areas (N = 19);
- Gas wells installed in 1985 (includes wells installed from 1978 to 1985) in the NWA with sandy soils (N = 15) (non-grazed areas);
- Gas wells installed in 1985 (includes wells installed from 1978 to 1985) in the NWA with loamy soils in grazed areas (N = 15);
- Controls in the NWA with sandy soils (randomly selected but on flat terrain) (N = 20) (non-grazed areas); and
- Controls in the NWA with loamy soil and subjected to grazing (randomly selected but on flat terrain) (N = 20).

Sites were selected (Figure 1) that were:

- Not within the DND approved buffer for a species at risk;
- Were a minimum of 50 metres from another well site, main pipeline or other type of disturbance (such as a road);
- Were not subject to fire during the years 2000 to 2006.

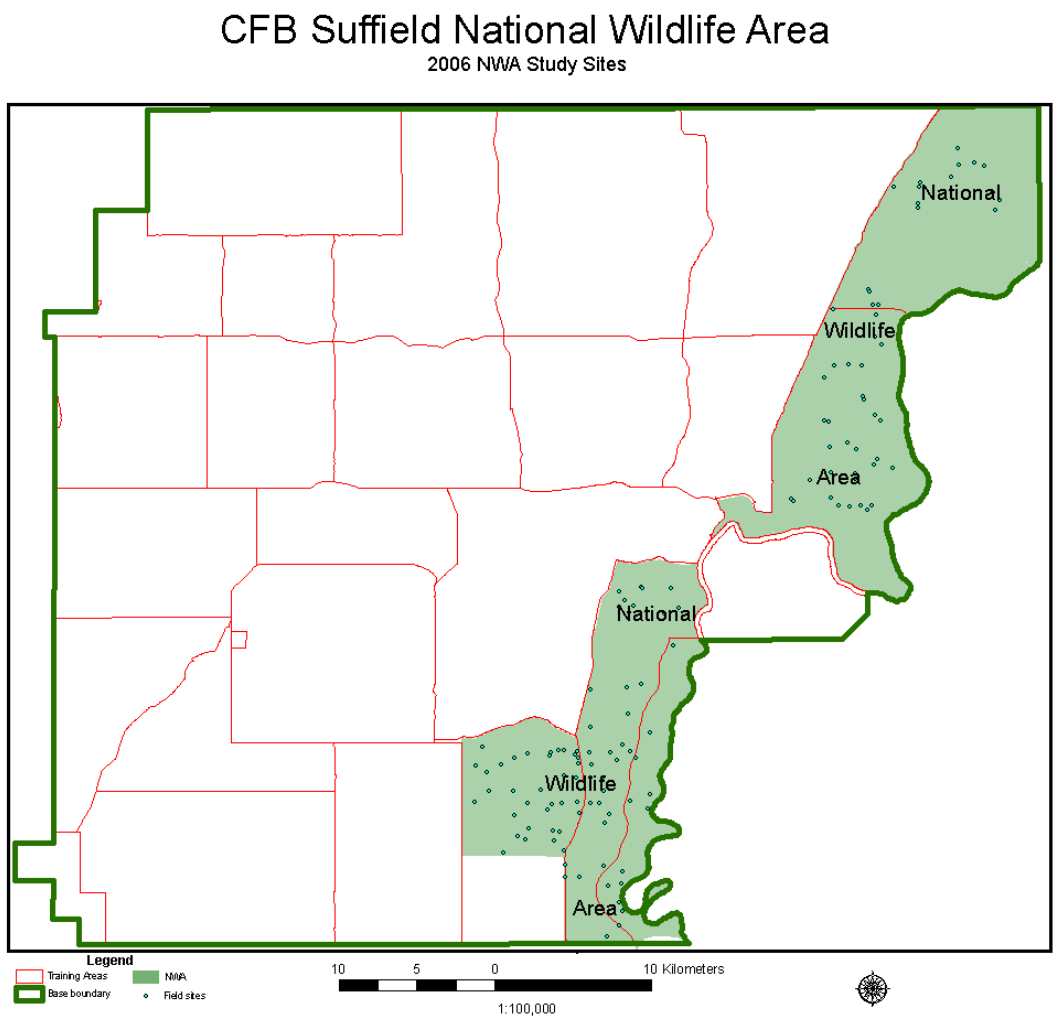

Figure 1. General locations of transect sites assessed in 2006 within the CFB Suffield National Wildlife Area.

At each of these sites the following information was collected:

- Date;
- GPS location (+/- 5 m);
- Digital photos of centre site, and in the direction of north, east, south and west and along the transect;
- Presence / description of any drilling waste, garbage; and
- Presence of rutts.

Vegetation sampling was recorded as follows:

1. Wells
    - 9 quadrats (50 cm by 20 cm; 20 cm side ran along transect) in a transect (at 0 metres, 2 m, 4 m, 6 m and 8 m on both sides of the well site) along the same slope and aspect of the well.
2. Pipeline

- 9 quadrats (50 cm by 20 cm; 20 cm side ran along transect) in a transect (at 0 metres, 2 m, 4 m, 6 m and 8 m on both sides of the pipeline). Transect ran at a 45 degree angle to the pipeline).

3. Control
    - 9 quadrats (50 cm by 20 cm, 20 cm side ran along transect) at 0 metres, 2 m, 4 m, 6 m, 8 m, 10 m, 12 m, 14 m and 16 m in a transect following the same slope and aspect.

For each quadrant the following were measured:

- Species abundance as a percentage per species (inventory);
- Species diversity (native and non-native; diversity = total number of species per quadrant);
- Species percent cover (native and non-native; totals per quadrant);
- Percent cover of bare ground per quadrant;
- Depth of topsoil (cm);
- Compaction (scale 1, 2, 3, 4, 5; 1 = loose soil, 5 = dense compact soil);
- Presence of rutts or erosion;
- Shear vane reading;
- Presence of grazing; and
- Number of access routes to well or site.

The shear vane strength at each of the sites was determined by recording three shear vane readings of the soil surface following ASTM Standard D 2573-94 (standard test method for field vane shear test in cohesive soil). The shear vane penetrated into the soil to a depth of 5 cm. The values were then averaged together. The shear vane used was a Pilcon direct reading hand shear vane tester. Measurements were recorded using a 19 mm diameter vane and the units were in kilopascals (kPa).

Timings

Data was collected between 27 August and 19 September 2006. Ideally the study would have been completed earlier in the season to assess the vegetation before senescing commenced, but was not possible due to training constraints.

Access

A NWA Access Permit was obtained from CFB Suffield prior to commencement of fieldwork. A 4x4 truck was used to access the sites, while using only existing routes and roads. Other sites were accesses only by foot. The NWA was not accessed during or immediately following heavy rainfall in order to minimize the impacts to the soil and vegetation. No garbage or debris was left within the NWA. No permanent markers were left to mark transects or sites. Radio contact was maintained with CFB Suffield Range Control. Sites were accessed within the Base only after receiving permission from Range Control.

Statistical Analysis

Statistical analysis was completed using Minitab Statistical Software for Windows, Release 14. Normality was determined using the Anderson-Darling Normality Test.

Tests for equal variances were completed with the acceptable value for both tests being a probability level of 0.05. Analysis of variance was completed using a one-way analysis of variance (ANOVA). ANOVAs were used to determine statistical significance between well or pipeline transects and the control transects. ANOVA, statistical significance was determined at the probability level (α) of 0.05. Outliers were removed and other groups were randomly reduced to allow for similar samples sized between groups. Two sample t-tests were completed to determine if there were significant differences between the well or pipeline centre and the quadrants located at 8 m distance (or end of transect).

Sample sizes used for comparison were relatively small, due to Base access restrictions as well as limited personnel resources to complete the required fieldwork. Sample sizes are of a sufficient size to only pick up on strong significant differences between variables. Research was completed to detail and document specific impacts of gas development within the NWA, an ecologically protected area of CFB Suffield. Although, the small sample sizes are not strong enough to demonstrate with absolute certainty that there are not impacts, the precautionary principle allows National Defence to conclude that there are serious concerns if significant differences are identified based on this report.

Data was compared as follows:

- Differences between wells installed in 1985 and control sites within in sandy soils;
- Differences between wells installed in 1985 and control sites within in loamy soils subjected to grazing;
- Differences between pipelines installed in 1985 and control sites within sandy soils;
- Differences between pipelines installed in 1985 and control sites within loamy soils subjected to grazing;
- Differences between wells installed in 1997 and control sites within in loamy soils subjected to grazing;
- Differences between pipelines installed in 1997 and control sites within loamy soils subjected to grazing;
- Differences between wells installed in 2000 and control sites within in sandy soils;
- Differences between wells installed in 2000 and control sites within in loamy soils subjected to grazing;
- Differences between pipelines installed in 2000 and control sites within sandy soils;
- Differences between pipelines installed in 2000 and control sites within loamy soils subjected to grazing
- Differences between well centre site and quadrant at 8 m in each direction; and
- Differences between pipeline centre site and quadrant at 8 m in each direction.

4.0 Results

Vehicle Tracks

Table 1 shows that all sites, regardless of a well, pipeline or control site were all subjected to vehicle traffic that was recent enough to leave distinguishing marks in the soil and vegetation. Of a total of 208 transects examined within the NWA, only 6 did not have permanent signs of vehicle use. Note that tracks were distinguished separately from access routes, as the access routes were easily identified off of the main trail or road. The tracks represent vehicles that braided a trail, drove off the existing access route to the location, and more often were tracks found circling the site when the vehicle had travelled via a different direction then the main map identified access route. The numbers of access routes per site are detailed immediately following Table 1.

Table 1. Number of vehicle tracks (two tire tracks per) located within a 25 m radius of the transect centre point.

Well /Pipeline/Control (# transects)	**Year**	**Soil type**	**Number of transect with 1, 2, 3, 4, or 5 vehicle tracts present**					
			0	**1**	**2**	**3**	**4**	**5**
Well (15)	1985	Sand		9	5	1		
Pipeline (15)	1985	Sand		14	1			
Well (15)	1985	Loam		8	5	2		
Pipeline (15)	1985	Loam	2	8	5			
Well (19)	1997	Loam		10	4	1	2	2
Pipeline (19)	1997	Loam	1	11	5	1	1	
Well (15)	2000	Sand		14	1			
Pipeline (15)	2000	Sand	2	13				
Well (20)	2000	Loam		10	8	2		
Pipeline (20)	2000	Loam		12	6		2	
Control (20)		Sand	1	14	4			
Control (20)		Loam		9	12		1	

Number of Access Routes

Access routes were identified as the route that followed the main pipeline and in turn the tie-in pipelines, but may have detoured slightly depending on local topography and obstructions. Observation within the NWA in 2006 found that the majority of wells & pipeline did in fact have one access route. Figure 2 demonstrate the scale and impact from a typical trail within the NWA. Figure 3 demonstrates what the areas with more then one access route look like. However, 14 wells had 2 access routes, 2 wells has 3 access routes and 1 well had 4 access routes (Table 2).

Figure 2. Photo provide scale of impact of a frequently used access trail within the NWA.

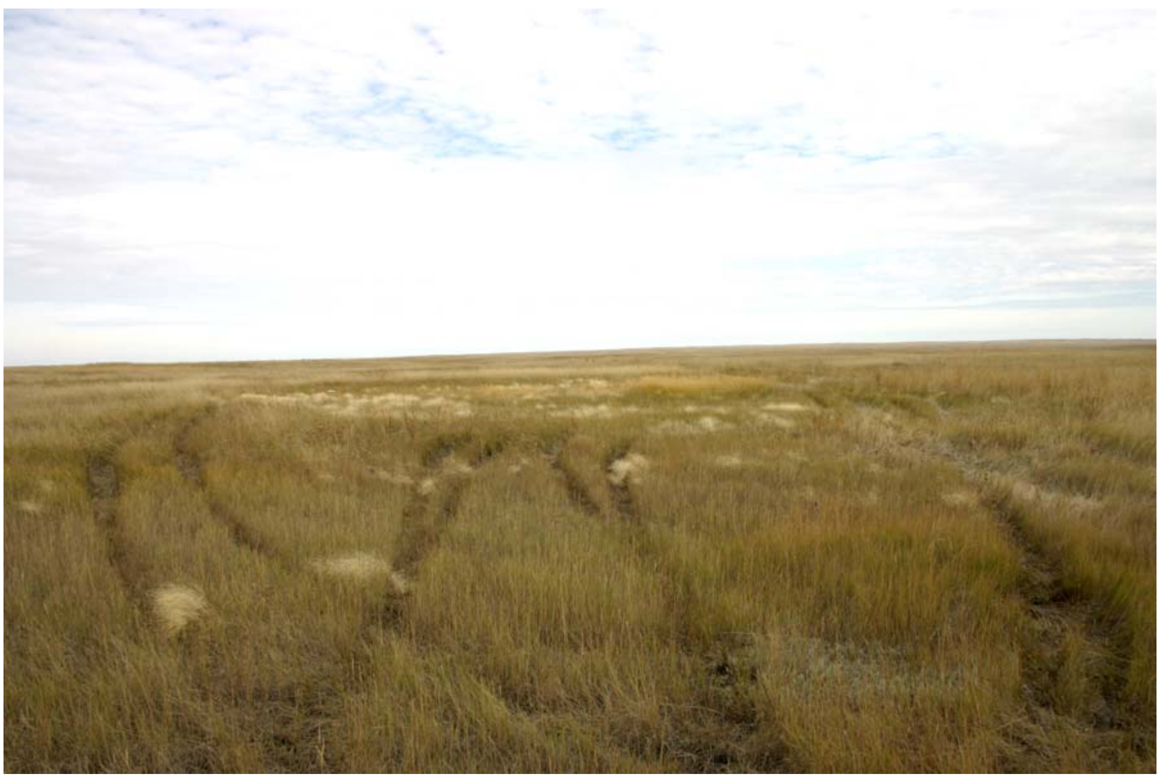

Figure 3. Photo demonstrates multiple vehicle route access to a well site.

Table 2. Number of access routes located within a 25 m radius of the transect centre point.

Well /Pipeline or Control (# transects)	**Year**	**Soil type**	**Number of transect with 1, 2, 3, 4 or 5 access routes**			
			1	**2**	**3**	**4**
Well / Pipeline (15)	1985	Sand	10	4	1	
Well / Pipeline (15)	1985	Loam	10	5		
Well / Pipeline (19)	1997	Loam	16	1	1	1
Well / Pipeline (15)	2000	Sand	13	2		
Well / Pipeline (20)	2000	Loam	18	2		

Soil Rutts

Soil vehicle rutts are defined as deep tire tracts were recorded within a 25 m radius of each of the transects. Rutts are formed from vehicle access when the soil is wet. Table 3 details the number of vehicle tire rutts (two tire tracks per) located within a 25 m radius of the transect centre point. Five of the control sites and 21 of the well or pipeline transect areas also contained rutts.

Table 3. Number of soil rutts from vehicles located within 25 m of the transect centre.

Well /Pipeline/Control (# transects)	**Year**	**Soil type**	**Number of Transect with 0, 1, 2, or 3 vehicle rutts**			
			0	**1**	**2**	**3**
Well (15)	1985	Sand	15			
Pipeline (15)	1985	Sand	15			
Well (15)	1985	Loam	12	1	1	
Pipeline (15)	1985	Loam	11	2	2	
Well (19)	1997	Loam	16	2		1
Pipeline (19)	1997	Loam	14	5		
Well (15)	2000	Sand	14	1		
Pipeline (15)	2000	Sand	14	1		
Well (20)	2000	Loam	15	2	2	1
Pipeline (20)	2000	Loam	19	1		
Control (20)		Sand	19	1		
Control (20)		Loam	16	2	2	

Erosion

Of the 84 well sites examined within this study, 57 of the well sites showed signs of erosion. The erosion was generally found immediately surrounding the well and/or the cattle gate/fence used to protect the well head (Figure 4, 5, 6). A total of 10 (out of 84) pipelines also demonstrated signs of erosion, as did 3 of the control sites.

Figure 4. A 2000 well head installed in the NWA. Photo demonstrates the bare ground existing 6 years following development. Photo also demonstrates erosion found at surrounding the caisson, as the caisson was originally placed at ground level.

Figure 5. Photo of one type of gas development above ground infrastructure within the NWA. The shed houses the well head as well as other gas development infrastructure. The fence restricts cattle access to the shed. Cattle were frequently found rubbing similar cattle fences within the NWA, resulting in increased erosion, bare ground and invasive immediately outside of the cattle fences.


Figure 6. Cow trail located in the southern portion of the NWA, close to a control transect. Cow trails contain only one tract and generally follow a straight path between the watering site or salt lick and the current grazing areas. Photo demonstrates the differences in erosion from cattle trails versus cattle rubbing at well sites. Photo also demonstrate the distinction between cattle trails and vehicle trails.

Drilling Mud, Garbage and Cement

Sites were examined for the presence of drilling mud, garbage and cement. During the examination of the transects and within a 25 m radius of the transect centre point, a total of 23 transects (and surrounding area) contained garbage and 23 sites contained drilling mud (same site did not always contain both). One site contained discard/leftover cement likely used in the creation of the well. The quantity of drilling mud was often not excessive in surface area, but was of a depth to ensure persistence of the material as well as to impact the underlying vegetation. The drilling mud was generally found within 5 metres of the well head. Garbage generally included discarded insulation from the well head, plastic sheeting, soda cans, paper and discarded wooded marking sticks. Figures 7 and 8 provide examples of waste found within the NWA.

Figure 7. Photo displays the sorts and general surface area of drilling mud and cement found at many well locations within the NWA.

Figure 8. Photo demonstrates surface area of drilling mud found close to a well site and pipeline (seen in the background) within in the NWA.

Topsoil Depth
Depth of topsoil demonstrates that some topsoil does remain in almost all areas (Table 4). Results do not demonstrate a significant effect from gas or pipeline development, given the natural variation found within the control sites.

Table 4. Topsoil depth at well head or pipeline centre point (cm).

Well /Pipeline/Control (# transects)	**Year**	**Soil type**	**Number of Transects per Topsoil depth (cm)**								
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**10**
Well (15)	1985	Sand		9	2	2		1		1	
Pipeline (15)	1985	Sand		15							
Well (15)	1985	Loam		5	5	3	2				
Pipeline (15)	1985	Loam	3	12							
Well (19)	1997	Loam		11	1	5	2				
Pipeline (19)	1997	Loam		17		2					
Well (15)	2000	Sand		10	2	2	1				
Pipeline (15)	2000	Sand		15							
Well (20)	2000	Loam		8	8	1	1	1		1	
Pipeline (20)	2000	Loam		20							
Control (20)		Sand		7	8	2		3			
Control (20)		Loam		7	4	5	1	3		1	1

Soil Compaction & Shear Vane Strength
Soil compaction values (Table 5) did not demonstrate a strong trend as being impacted by gas well or pipeline installation or by ongoing gas maintenance. Note however that only one reading was taken per transect, thus with a small sample size, it is possible that there are trends that were not captured during this analysis.

Table 5. Soil compaction at centre point of transect based on a scale of 1 to 5 (1 representing loose soil and 5 representing dense, compact soil).

Well /Pipeline/Control (# transects)	**Year**	**Soil type**	**Compaction scale (1 = loose soil; 5 = dense, compact soil)**					
			0	**1**	**2**	**3**	**4**	**5**
Well (15)	1985	Sand				3	7	5
Pipeline (15)	1985	Sand				2	8	5
Well (15)	1985	Loam				1	12	2
Pipeline (15)	1985	Loam	2			1	9	3
Well (19)	1997	Loam			1	3	14	1
Pipeline (19)	1997	Loam				1	15	3
Well (15)	2000	Sand		10	2	2	1	
Pipeline (15)	2000	Sand		15				
Well (20)	2000	Loam		1		6	12	1
Pipeline (20)	2000	Loam			2	5	12	1

Control (20)		Sand			1	4	13	2
Control (20)		Loam				5	13	2

Examination of the soil shear vane strength (Table 6) demonstrates that there are some impacts from gas development within the NWA, however the impacts are not consistent between wells and pipelines or between soil types within a year.

Table 6. Soil shear vane ANOVA results for the comparison between control transects and well or pipeline transects from 1985, 1997 or 2000 for sandy or loamy soils within the NWA. Table details the sample size (number of quadrants per control or well/pipeline (a total of 4 readings were taken per transect), the mean (=/- standard deviation) for both control transect as well as the developed transect. Table also details the F-statistic value, the P value, and total degrees of freedom for the ANOVA. The last column (yes=Y, no=N) details if there was a significant difference between the control and the developed transect.

Year	**Well or Pipeline**	**Soil Type**	**N**	**Control Transect**	**Developed Transect**	**F Value**	**P Value**	**Total DF**	**Signif**
1985	Well	Loam	60	46.7 (20.5)	26.3 (17.0)	9.19	0.003	119	Y
1985	Pipeline	Loam	60	46.7 (20.5)	32.0 (11.4)	23.50	0.000	119	Y
1985	Well	Sand	60	33.0 (14.5)	39.4 (16.5)	5.11	0.026	119	Y
1985	Pipeline	Sand	60	33.0 (14.5)	35.1 (14.5)	0.61	0.436	119	N
1997	Well	Loam	76	44.7 (19.3)	45.2 (19.1)	0.02	0.880	151	N
1997	Pipeline	Loam	76	44.7 (19.3)	35.2 (17.8)	9.68	0.002	151	Y
2000	Well	Loam	80	46.4 (20.4)	48.3 (19.9)	0.38	0.528	159	N
2000	Pipeline	Loam	80	16.4 (20.4)	38.4 (16.9)	7.22	0.008	159	Y
2000	Well	Sand	60	33.0 (14.5)	54.0 (21.0)	40.61	0.000	119	Y
2000	Pipeline	Sand	60	33.0 (14.5)	32.6 (12.9)	0.02	0.876	119	N

Percent cover of bare ground

Both wells and pipelines developed in 2000 for both sandy and loamy soils remain in a state that there is significantly more bare ground cover within the 16 metres centered on the impact compared to the control sites (Table 7). As well, wells installed in 1985 for sandy and loamy soils demonstrated this same long term impact. It is interesting to note that the 1997 loamy soil wells and pipelines as well as the pipelines from 1985 in loamy and sandy soils do not demonstrate this impact.

Table 7. Percent cover of bare ground ANOVA results for the comparison between control transects and well or pipeline transects from 1985, 1997 or 2000 for sandy or loamy soils within the NWA. Table details the sample size (number of quadrants per control or well/pipeline), the mean (=/- standard deviation) for both control transect as well as the developed transect. Table also details the F-statistic value, the P value, and total degrees of freedom for the ANOVA. The last column (yes=Y, no=N) details if there was a significant difference between the control and the developed transect.

Year	Well or Pipeline	Soil Type	N	Control Transect	Developed Transect	F Value	P Value	Total DF	Signif
1985	Well	Loam	134	9.0 (8.8)	24.4 (23.4)	50.90	0.000	267	Y
1985	Pipeline	Loam	134	9.0 (8.8)	8.6 (14.8)	0.06	0.803	267	N
1985	Well	Sand	134	5.1 (6.9)	13.8 (16.8)	30.8	0.000	267	Y
1985	Pipeline	Sand	134	5.1 (6.9)	4.2 (8.7)	0.94	0.332	267	N
1997	Well	Loam	171	8.7 (8.4)	20.3 (22.3)	40.97	0.000	341	N
1997	Pipeline	Loam	171	8.7 (8.4)	8.6 (12.9)	0.00	0.984	341	N
2000	Well	Loam	179	8.4 (8.6)	27.8 (29.0)	78.62	0.000	357	Y
2000	Pipeline	Loam	179	8.5 (8.3)	12.9 (16.0)	10.79	0.001	357	Y
2000	Well	Sand	135	5.4 (7.0)	13.0 (16.2)	24.90	0.000	269	Y
2000	Pipeline	Sand	135	5.1 (6.9)	7.8 (10.7)	6.28	0.013	269	Y

Percent Cover of Native Species

In all transects examined, the percent cover of native species is significantly higher for the control transect then the developed transect except for the 1985 loam pipeline which has a significantly higher percent cover of native species then the control transects. The 1997 loam pipeline did not differ significantly from the control transects in the percent cover of native species (Table 8).

Table 8. Percent cover of native mixed grass prairie ANOVA results for the comparison between control transects and well or pipeline transects from 1985, 1997 or 2000 for sandy or loamy soils within the NWA. Table details the sample size (number of quadrants per control or well/pipeline), the mean (=/- standard deviation) for both control transect as well as the developed transect. Table also details the F-statistic value, the P value, and the total degrees of freedom for the ANOVA. The last column (yes=Y, no=N) if there was a significant difference between the control and the developed transect.

Year	Well or Pipeline	Soil Type	N	Control Transect	Developed Transect	F Value	P Value	Total DF	Signif
1985	Well	Loam	135	82.3 (17.9)	55.0 (33.2)	70.74	0.000	269	Y
1985	Pipeline	Loam	135	82.3 (17.9)	87.5 (21.1)	4.69	0.031	269	Y
1985	Well	Sand	135	91.2 (15.1)	79.2 (27.8)	30.30	0.000	269	Y
1985	Pipeline	Sand	135	91.2 (15.1)	85.4 (26.1)	5.00	0.026	269	Y

1997	Well	Loam	171	82.6 (18.0)	74.3 (27.6)	10.83	0.001	341	Y
1997	Pipeline	Loam	171	82.6 (18.0)	82.2 (22.7)	0.05	0.831	341	N
2000	Well	Loam	179	83.4 (17.9)	63.6 (32.6)	50.86	0.000	357	Y
2000	Pipeline	Loam	179	83.4 (17.9)	80.5 (22.6)	1.84	0.176	357	Y
2000	Well	Sand	135	91.2 (15.1)	83.9 (21.3)	10.34	0.001	269	Y
2000	Pipeline	Sand	135	91.2 (15.1)	87.3 (16.4)	3.96	0.048	269	Y

Percent Cover of Non-Native Species
The 1985 loam wells, 1997 loam wells and pipelines, the 2000 loam well and pipelines and the 2000 sand pipelines all have a significant increase in their non-native percent cover compared to the control transects (Table 9). The remainder of the transects did not differ significantly from the control sites.

Table 9. Percent cover of non-native mixed grass prairie ANOVA results for the comparison between control transects and well or pipeline transects from 1985, 1997 or 2000 for sandy or loamy soils within the NWA. Table details the sample size (number of quadrants per control or well/pipeline), the mean (=/- standard deviation) for both control transect as well as the developed transect. Table also details the F-statistic value, the P value, and the total degrees of freedom for the ANOVA. The last column (yes=Y, no=N) if there is a significant difference between the control and the developed transect.

Year	**Well or Pipeline**	**Soil Type**	**N**	**Control Transect**	**Developed Transect**	**F Value**	**P Value**	**Total DF**	**Signif**
1985	Well	Loam	135	1.8 (5.7)	13.8 (23.2)	33.8	0.000	269	Y
1985	Pipeline	Loam	135	1.8 (5.7)	1.6 (4.8)	0.15	0.695	269	N
1985	Well	Sand	135	2.1 (5.2)	2.5 (10.4)	0.14	0.706	269	N
1985	Pipeline	Sand	135	2.1 (5.2)	2.6 (8.9)	0.36	0.549	269	N
1997	Well	Loam	170	1.6 (5.2)	4.6 (10.7)	10.55	0.001	339	Y
1997	Pipeline	Loam	170	1.6 (5.2)	8.2 (16.7)	24.24	0.000	339	Y
2000	Well	Loam	179	1.6 (5.1)	9.4 (21.2)	23.41	0.000	359	Y
2000	Pipeline	Loam	179	1.6 (5.1)	5.3 (14.9)	10.19	0.002	359	Y
2000	Well	Sand	135	2.1 (5.2)	2.9 (10.1)	0.66	0.418	269	N
2000	Pipeline	Sand	135	2.1 (5.2)	5.6 (14.1)	7.35	0.007	269	Y

Native Species Diversity
Examination of the native species diversity shows that there are significantly fewer native species within the 1985 loam wells and pipelines, 1985 sandy wells, 1997 loamy wells, and all sandy and loamy wells and pipelines installed in 2000 when compared to the control transects (Table 10). For all other pipeline transects categories examined, there was not a significant difference in the native species diversity.

Table 10. Native mixed grass prairie diversity ANOVA results for the comparison between control transects and well or pipeline transects from 1985, 1997 or 2000 for sandy or loamy soils within the NWA. Table details the sample size (number of quadrants per control or well/pipeline), the mean (=/- standard deviation) for both control transect as well as the developed transect. Table also details the F-statistic value, the P value, and the total degrees of freedom for the ANOVA. The last column (yes=Y, no=N) if there is a significant difference between the control and the developed transect.

Year	**Well or Pipeline**	**Soil Type**	**N**	**Control Transect**	**Developed Transect**	**F Value**	**P Value**	**Total DF**	**Signif**
1985	Well	Loam	135	6.0 (1.7)	4.4 (2.2)	42.50	0.000	269	Y
1985	Pipeline	Loam	135	6.0 (1.7)	5.1 (1.9)	15.79	0.000	269	Y
1985	Well	Sand	135	4.8 (1.7)	3.6 (2.1)	29.48	0.000	269	Y
1985	Pipeline	Sand	135	4.8 (1.7)	4.7 (1.9)	0.47	0.493	269	N
1997	Well	Loam	171	4.9 (1.6)	0.8 (1.0)	748.26	0.000	341	Y
1997	Pipeline	Loam	171	4.9 (1.6)	4.9 (2.3)	0.09	0.763	341	N
2000	Well	Loam	179	4.9 (1.6)	4.1 (2.0)	21.27	0.000	359	Y
2000	Pipeline	Loam	179	4.9 (1.6)	4.9 (2.1)	0.20	0.659	359	Y
2000	Well	Sand	135	5.9 (1.6)	4.6 (1.8)	43.04	0.000	269	Y
2000	Pipeline	Sand	135	6.0 (1.7)	5.1 (1.5)	23.09	0.000	269	Y

Non-Native Species Diversity

Examination of non-native diversity (Table 11) demonstrates that there was a higher non-native species diversity for 1985 wells (loam soil), 1997 wells and pipelines (loam soils) and 2000 wells and pipelines (loam soils) when compared to the control transects. Significant differences were not found for the remainder of the categories, except that there was a significant increase found within the control transect versus the 2000 wells in sandy soil.

Table 11. Non-native mixed grass prairie diversity ANOVA results for the comparison between control transects and well or pipeline transects from 1985, 1997 or 2000 for sandy or loamy soils within the NWA. Table details the sample size (number of quadrants per control or well/pipeline), the mean (=/- standard deviation) for both control transect as well as the developed transect. Table also details the F-statistic value, the P value, and the total degrees of freedom for the ANOVA. The last column (yes=Y, no=N) if there is a significant difference between the control and the developed transect.

Year	**Well or Pipeline**	**Soil Type**	**N**	**Control Transect**	**Developed Transect**	**F Value**	**P Value**	**Total DF**	**Signif**
1985	Well	Loam	135	0.4 (0.7)	0.7 (0.8)	9.08	0.003	269	Y
1985	Pipeline	Loam	135	0.4 (0.7)	0.4 (0.7)	0.03	0.856	269	N
1985	Well	Sand	135	0.4 (0.7)	0.4 (0.7)	0.81	0.368	269	N
1985	Pipeline	Sand	135	0.4 (0.7)	0.4 (0.7)	0.03	0.865	269	N
1997	Well	Loam	171	0.4 (0.7)	0.8 (1.0)	15.36	0.000	341	Y
1997	Pipeline	Loam	171	0.4 (0.7)	0.8 (0.8)	13.97	0.000	341	Y
2000	Well	Loam	179	0.5 (0.7)	1.0 (1.1)	34.89	0.000	259	Y

2000	Pipeline	Loam	179	0.5 (0.7)	0.7 (1.0)	7.69	0.006	259	Y
2000	Well	Sand	135	0.7 (0.9)	0.4 (1.0)	7.69	0.006	359	Y
2000	Pipeline	Sand	135	0.7 (0.9)	0.6 (0.7)	0.59	0.442	269	N

Variation with Distance from Impact
Further analysis was completed to determine the extent within a transect that significant difference existed per type of measurement recorded. For example, by comparing the centre point to the end point of a transect (at 8 metres out), if there was a significant difference between the two areas, this demonstrates that the impacts extend beyond the immediate area of the well or the pipeline. As well, the examination of the non-native species percent cover and diversity provide an indication as to whether current or historical methods to control or reduce the non-native species establishment are effective.

Examination of the percent bare ground cover (Table 12) shows that there is a significant decrease at 8 metres from the source of development when compared to the centre point for 7/10 of the categories examined.

Table 12 Percent cover bare ground t-test results at transect centre versus at transect ends (8 metre distance in both directions).

Year	Well or Pipeline	Soil Type	N	Mean =/- St. Dev at transect Centre	Mean =/- St. Dev at transect 8 m from transect centre	P value	Significant Difference
1985	Well	Loam	30	41.5 (24.0)	18.3 (18.1)	0.000	Yes
1985	Pipeline	Loam	30	10.0 (10.0)	6.9 (8.9)	0.210	No
1985	Well	Sand	30	21.7 (18.6)	9.3 (10.5)	0.003	Yes
1985	Pipeline	Sand	30	10.0 (14.4)	2.7 (2.7)	0.012	Yes
1997	Well	Loam	38	50.0 (24.0)	15.4 (19.1)	0.000	Yes
1997	Pipeline	Loam	38	24.5 (19.7)	7.2 (11.2)	0.000	Yes
2000	Well	Loam	40	57.5 (35.9)	22.6 (20.9)	0.000	Yes
2000	Pipeline	Loam	40	24.5 (18.9)	8.0 (8.5)	0.000	Yes
2000	Well	Sand	30	11.3 (16.2)	10.7 (12.6)	0.860	No
2000	Pipeline	Sand	30	7.3 (12.0)	6.3 (9.2)	0.719	No

Table 13 demonstrates that for native species percent cover, all but one of the comparisons showed a significant increase in percent cover of the native plant species at a distance of 8 metres versus at the impact site (or centre of the transect).

Table 13 Native Species percent cover t-test results at transect centre versus at transect ends (8 metre distance in both directions)

Year	Well or Pipeline	Soil Type	N	Mean =/- St. Dev at transect Centre	Mean =/- St. Dev at transect 8 m from transect centre	P value	Significant Difference

1985	Well	Loam	30	45.5 (28.8)	62.0 (32.5)	0.041	Yes
1985	Pipeline	Loam	30	85.2 (16.5)	93.47 (9.72)	0.022	Yes
1985	Well	Sand	30	71.7 (21.2)	90.3 (14.1)	0.000	Yes
1985	Pipeline	Sand	30	79.1 (23.5)	95.2 (9.8)	0.001	Yes
1997	Well	Loam	38	31.4 (24.6)	83.3 (23.0)	0.000	Yes
1997	Pipeline	Loam	38	61.2 (32.9)	87.9 (18.1)	0.000	Yes
2000	Well	Loam	40	24.0 (26.0)	74.7 (29.5)	0.000	Yes
2000	Pipeline	Loam	40	52.7 (31.1)	90.6 (11.2)	0.000	Yes
2000	Well	Sand	30	88.0 (17.9)	88.2 (18.5)	0.966	No
2000	Pipeline	Sand	30	76.9 (30.0)	91.0 (12.6)	0.023	Yes

Table 14 demonstrates that with respect to the percent cover of non-native plant species, only roughly half of the comparisons showed a significant difference. All significant differences demonstrates a drastic decrease in non-native percent cover at 8 metres then at the impact site (or centre of transect).

Table 14 Non-Native Species percent cover t-test results at transect centre versus at transect ends (8 metre distance in both directions)

Year	**Well or Pipeline**	**Soil Type**	**N**	**Mean =/- St. Dev at transect Centre**	**Mean =/- St. Dev at transect 8 m from transect centre**	**P value**	**Significant Difference**
1985	Well	Loam	30	13.3 (25.3)	10.7 (20.1)	0.669	No
1985	Pipeline	Loam	30	3.33 (1.2)	0.67 (1.1)	0.043	Yes
1985	Well	Sand	30	16.0 (18.4)	4.3 (12.7)	0.002	Yes
1985	Pipeline	Sand	30	16.5 (26.2)	8.4 (17.5)	0.223	No
1997	Well	Loam	38	7.4 (16.6)	1.5 (5.7)	0.076	No
1997	Pipeline	Loam	38	9.0 (7.5)	7.5 (38.2)	0.856	No
2000	Well	Loam	40	33.0 (31.1)	5.5 (14.4)	0.000	Yes
2000	Pipeline	Loam	40	22.8 (27.5)	1.2 (3.3)	0.000	Yes
2000	Well	Sand	30	2.3 (7.6)	4.4 (13.8)	0.454	No
2000	Pipeline	Sand	30	14.7 (24.3)	2.9 (9.1)	0.014	Yes

Examination of Table 15 demonstrates that except for 1985 wells in loamy soils, there was a significant increase in native species diversity at 8 metres distance from the disturbance.

Table 15 Native Species Diversity t-test results at transect centre versus at transect ends (8 metre distance in both directions)

Year	**Well or Pipeline**	**Soil Type**	**N**	**Mean =/- St. Dev at transect Centre**	**Mean =/- St. Dev at transect 8 m from transect centre**	**P value**	**Significant Difference**
1985	Well	Loam	30	3.2 (1.8)	4.3 (1.9)	0.037	Yes

1985	Pipeline	Loam	30	3.3 (1.8)	4.2 (1.9)	0.067	No
1985	Well	Sand	30	3.7 (1.4)	5.8 (2.1)	0.000	Yes
1985	Pipeline	Sand	30	4.7 (1.1)	5.9 (1.4)	0.000	Yes
1997	Well	Loam	38	3.3 (2.1)	5.6 (1.6)	0.000	Yes
1997	Pipeline	Loam	38	3.4 (1.6)	5.3 (2.2)	0.000	Yes
2000	Well	Loam	40	2.1 (1.6)	5.2 (2.1)	0.000	Yes
2000	Pipeline	Loam	40	3.6 (1.8)	5.2 (1.9)	0.000	Yes
2000	Well	Sand	30	3.0 (1.2)	5.1 (1.5)	0.000	Yes
2000	Pipeline	Sand	30	3.9 (1.6)	5.7 (1.4)	0.000	Yes

Examination of Table 16 demonstrates that for 1985 loam wells, 2000 loam wells and pipelines and for 2000 sandy wells, there was a significant decrease at 8 metres from impact with respect to non-native species diversity. For the 1997 loam wells there was a significant increase in the number of non-native plant species. For the remainder of the transects, there was not a significant difference between the centre of the transect versus a distance of 8 metres.

Table 16 Non-Native Species Diversity t-test results at transect centre versus at transect ends (8 metre distance in both directions)

Year	**Well or Pipeline**	**Soil Type**	**N**	**Mean =/- St. Dev at transect Centre**	**Mean =/- St. Dev at transect 8 m from transect centre**	**P value**	**Significant Difference**
1985	Well	Loam	30	1.0 (1.1)	0.4 (0.6)	0.013	Yes
1985	Pipeline	Loam	30	0.6 (0.7)	0.5 (0.7)	0.466	No
1985	Well	Sand	30	0.7 (1.1)	0.4 (0.6)	0.113	No
1985	Pipeline	Sand	30	0.7 (1.0)	0.5 (0.8)	0.463	No
1997	Well	Loam	38	2.1 (1.3)	3.4 (2.6)	0.012	Yes
1997	Pipeline	Loam	38	1.7 (1.7)	2.5 (2.6)	0.115	No
2000	Well	Loam	40	2.1 (1.3)	1.0 (1.0)	0.000	Yes
2000	Pipeline	Loam	40	1.5 (1.4)	0.5 (0.7)	0.000	Yes
2000	Well	Sand	30	0.2 (0.4)	0.7 (0.9)	0.005	Yes
2000	Pipeline	Sand	30	0.6 (0.6)	0.7 (0.7)	0.435	No

5.0 Discussion

Examination of vehicle tracks within the NWA at control areas, wells and pipelines showed that few areas within the protected NWA are not subjected to vehicle traffic. Current Base policy requires that drivers remain on existing road and trails, thus within the NWA, it was anticipated to find a lack of trails within the control areas and only one vehicle track per well or pipeline. Two wells established in 1997 had evidence of 5 trails into the well site. A total of 21 transect areas contained rutts, demonstrating as well that these sites were being accessed during times when the soil was wet. Base Range Standing Orders prohibit range access during and immediately following heavy rainfall or moisture, as a measure to help protect the soil and vegetation structure of the mixed grass prairie. Thus concern remains as to why the sheer quantity of vehicle tracks exist within the NWA and future effort by the Base should be directed towards ensuring vehicles travel only by approved access routes.

Wells and their associated pipelines within the NWA are accessed by the Gas Companies at various times per year or month in order to ensure the safe and effective operation of the infrastructure. Access to wells and pipelines is via an access route/road/trail that is identified on a map. Generally, the access routes follow the main pipeline and in turn the tie-in pipelines, but may detour depending on local topography and obstructions. Policy within CFB Suffield restricts access to the wells and pipelines to one access route per. Observation within the NWA in 2006 found that the majority of wells & pipeline did in fact have one access route. However, 14 wells had two access routes, 2 wells has three access routes and well had four access routes. Access routes are limited in order to restrict the total surface area of disturbed soil and vegetation as well as to minimize fragmentation and linear corridors within the NWA and CFB Suffield ecosystem. Additional effort by the Base is thus required to ensure that all vehicles remain on the Base approved access routes.

Protection of the mixed grass prairie within the NWA is the top priority. Signs of erosion on wells and pipelines is not encouraging, as this is the prime location for the establishment of non-native vegetation species. Evidence of drilling mud, cement or garbage within the NWA demonstrates a lack of respect for ecosystem and wildlife protection as well as for Base policy, as Range Standing Orders strictly prohibit the discarding of any material within the NWA.

Topsoil depth within the NWA and CFB Suffield vary naturally from roughly 3 to 12 cm in depth. Examination of topsoil depth at wells and pipeline did indicate that there is still some topsoil remaining on these historically disturbed sites, although due to general variation even within the control sites, it is not possible at this time to determine from these results if there is a significant impact from historical gas and pipeline development to the depth of topsoil. Note only one record of topsoil depth was recorded per transect. It is recommended that future studies re-examine the potential impact of gas and pipeline installation and maintenance to topsoil depth, as the organic matter located within the topsoil is essential for vegetation abundance and health. Similar studies are required for assessing the impacts to soil structure and strength.

The percent cover of bare ground increase in the 1985 wells, as well as the 2000 wells and pipelines demonstrate that there are some short and long term impacts from gas development within the NWA. The results for 1997 do not demonstrate the same impacts potentially due to differences in installation techniques, the seasonal timings of installation or the presence of positive climatic conditions to encourage ground cover to establish. Note that these results can only be interpreted after determining the actual ground cover that establishes to establish whether the increase in ground cover in 1997 was due to non-native species infestations.

When examining the percent cover of native species diversity, there was no significant difference in the 1997 loam pipeline and there was a significant increase in the 1985 loam pipeline. However, for the remainder of the transects there was a significant decrease in the percent cover of native species within the developed areas then the control areas. This result demonstrates that the above-mentioned increase in bare ground also occurs in general with a decrease in native species percent cover, a valued ecosystem component of the NWA.

The 1985 loam wells, 1997 loam wells and pipelines, the 2000 loam well and pipelines and the 2000 sand pipelines all have a significant increase in their non-native percent cover. The remainder of the transects did not differ significantly from the control sites. This demonstrates as well, that for the impacted areas, the vegetative cover establishing on the disturbed sites contain significant land cover of non-native species.

When the cumulative impacts from an increase in bare ground and non-native species cover is combined with a decrease in native species percent cover, this tells a story of serious impact to the NWA from gas development and maintenance. Time is considered a strong factor to removing or reducing the impacts from gas development, as strong, healthy ecosystems tend to return to a new equilibrium that can ensure the persistence of the ecosystem. Since impacts from development from 22 years ago are still being observed within the NWA, this indicates that the mixed grass prairie ecosystem within the NWA is very slow to return and likely will require a minimum of 40 years to allow the ecosystem and its components to resemble those existing before gas development. Note that this estimate of 40 years is an estimate, as it could take far longer then this. This is a serious problem that must be addressed in management plans and policy at CFB Suffield before any additional impacts are permitted within the NWA.

Examination of the native species diversity shows that there are significantly fewer native species within the 1985 loam wells and pipelines, 1985 sandy wells, 1997 loamy wells, and all sandy and loamy wells and pipelines installed in 2000 when compared to the control sites. Where as for the non-native diversity, there was a higher non-native species diversity for 1985 wells (loam soil), 1997 wells and pipelines (loam soils) and 2000 wells and pipelines (loam soils). This demonstrates that in general, gas development within the NWA is reducing the native species diversity and increasing the non-native diversity.

Further analysis was completed to determine the extent within a transect that significant differences existed per type of measurement recorded. For example, by comparing the centre point to the end point of a transect at 8 metres out, if there was a significant difference between the two areas, this demonstrates that the impacts extend beyond the immediate area of the well or the pipeline. As well, the examination of the non-native species percent cover and diversity provide an indication as to whether current or historical methods to control or reduce the non-native species establishment are effective.

Examination of the percent bare ground cover showed that there is a significant decrease at 8 metres from the source of development when compared to the centre point for 7/10 categories examined. This is important to note, as it demonstrates that either there is less disturbance as you move away from the impact source. In general for percent cover of native plant species as well as diversity, both improved at a distance of 8 metres from the impact or transect centre. For non-native species diversity and percent cover, these generally decreased at a distance of 8 metres from the impact or transect centre. Although it is concerning that impacts can still be found at a distance of 8 metres from impact and that there are significant numbers and percent covers of non-native species and bare ground, it is somewhat promising that the impact are less then at well site. Difficulty remains in determining if the quadrants at 8 metres are actually self-repairing and naturally restoring themselves, or if with time that the non-native species are actually continuing to spread into the surrounding healthy mixed grass prairie. This is an areas of research that should be examined soon, so that Base management plans and policies can be updated in a timely fashion to ensure that no further invasion or spread of non-native species occurs with the prized NWA of CFB Suffield. Based on research observations, it is obvious that current management and restoration techniques are not effective for protecting the health and percent cover or native mixed grass prairie and must be updated.

The NWA is a prize ecosystem and landscape to the people of Canada as seen by its recent designation as a NWA. The NWA is bordered by the South Saskatchewan River on the east side and by farming on the remaining three sides. The NWA thus serves as a source population for native species as well as for the highly valued species at risk. Any impact to the NWA will affect these valued ecosystem components as well as the ecosystem systems, cycles and functions required to support the valued ecosystem components. Additional research, management planning and policy revisions are required to ensure that no irreversible impacts are allowed to occur within the NWA that could impact any values ecosystem component or affect wildlife conservation.

Additional concerns regarding gas development that arose while conducting this research within the NWA was the close proximity of wells and infrastructure to permanent and ephemeral wetlands. Wetlands are a valued ecosystem component and can be seriously impacted by geographically close development. Figure 9 demonstrates the close proximity of a well to a permanent wetland within the NWA. The close proximity of the well could result in water contamination, changes to overland water flow, or changes to species abundance or diversity (including species at risk) within the essential wetland buffer area.

Figure 9. Photo of wetland within the NWA, showing the distance of the well head (and thus part of the tie-in pipeline) to the permanent wetland.

Another concern with respect to shallow gas development within the NWA includes the shear abundance of disturbances. Figure 10 demonstrates that there are many other sources of disturbance from gas development in additional to the actual well and pipeline. In Figure 10, the well is located at the back right of the photo. Four other small caissons are in the immediate vicinity of the well. These caissons are isolation values that can be used during maintenance or in cases of emergency to stop the flow of gas within a pipeline.

Figure 10. Photo demonstrates increased impacts of below ground gas infrastructure within the NWA. The rear of the photo is the below ground well head, where as in the fore ground are four shut-off valves for the pipelines. Note the poor state of the ply-wood cover, which can be a cause of wildlife injury as the mammals hoofs fall through the gaps while running past. Note as well that one of the shut-off caisson cover grates was left open, thereby creating a health and safety concern for all that access the NWA,

Figure 11 is a close up of a caisson within Figure 10. This photo highlights another concern of gas development within the NWA. These caissons exist so that the gas infrastructure is located below ground, with the hopes of minimizing the impact to military training and research. The caissons are covered with a grate that can be lifted open to allow access to the below ground infrastructure. When these grates are not properly closed (as required by both Base and Industry policy) a serious health and safety infraction occurs. When traversing the land quickly, it would be easy for people or wildlife to fall within the caisson and cause serious personal injury.

As an additional safety precaution, the Base requires that the caissons are covered with plywood, as this will prevent the hooves of mammals from falling between the bars of the grates, potentially resulting in broken bones as the animals traverse quickly and often in poor visibility. The ply-wood also prevent small animals from falling into the caissons and either injuring themselves or realizing that no exit route exits. Figure 11 demonstrates that the ply-wood was often in poor shape or non-existent.

Figure 11. NWA 2006 photo of cover for a pipeline shut-off (isolation) value demonstrating the poor ply-wood cover. This is an up close image of a portion of Figure 10.

In conclusion, this research report highlights that there are long term effects to the ecosystem of CFB Suffield NWA. There remain many areas for further research including detailed examination of the impacts of gas development to the soil structural, physical and biological properties within the NWA. Effects identified within this report can be used to develop appropriate management plans and policies to ensure the long term protection of the health and function of the NWA ecosystem as well as to ensure that gas operations do not impact wildlife conservation.

6.0 Potential Gas Development Indicators

In addition to the creation of indicators from the data collected above, the following may be used as indicators for measuring the ecological sustainability of gas development at CFB Suffield (note that this is not an exhaustive list):

1. Management plan for weed and invasive species has been put in place for both well sites and pipelines;
2. Management plan put in place for all species at risk (federal and provincial)
3. Creation of Range Standing Orders with detailed information of what is acceptable on the Base with respect to oil and gas development;
4. Documentation that oil and gas personnel working on the Base have read the Range Standing Orders as well as all amendments;
5. Whether environmental training is given to all who enter the Base (knowledge is the key to improving behaviour);
6. Pre-construction / drilling environmental assessments conducted by qualified staff that ensure that:
    a. Species at risk are not present on lease site;
    b. Optimal location of wells and pipelines from a landscape perspective; and
    c. That development does not occur within 100 metres of a wetland.
7. Post-construction / drilling inspections are conducted by a qualified person to ensure that:
    a. All drilling waste are cleaned up from site;
    b. That hydrocarbon spills are immediately cleaned up;
    c. That erosion is minimized by restoration procedures (both at well sites and on access routes and right-of –ways);
    d. Presence of only one access route per well with maximizations of existing routes; and
    e. That access routes and right-of-ways do not exceed the allowable width.

7.0 Reference

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