

SECTION 6

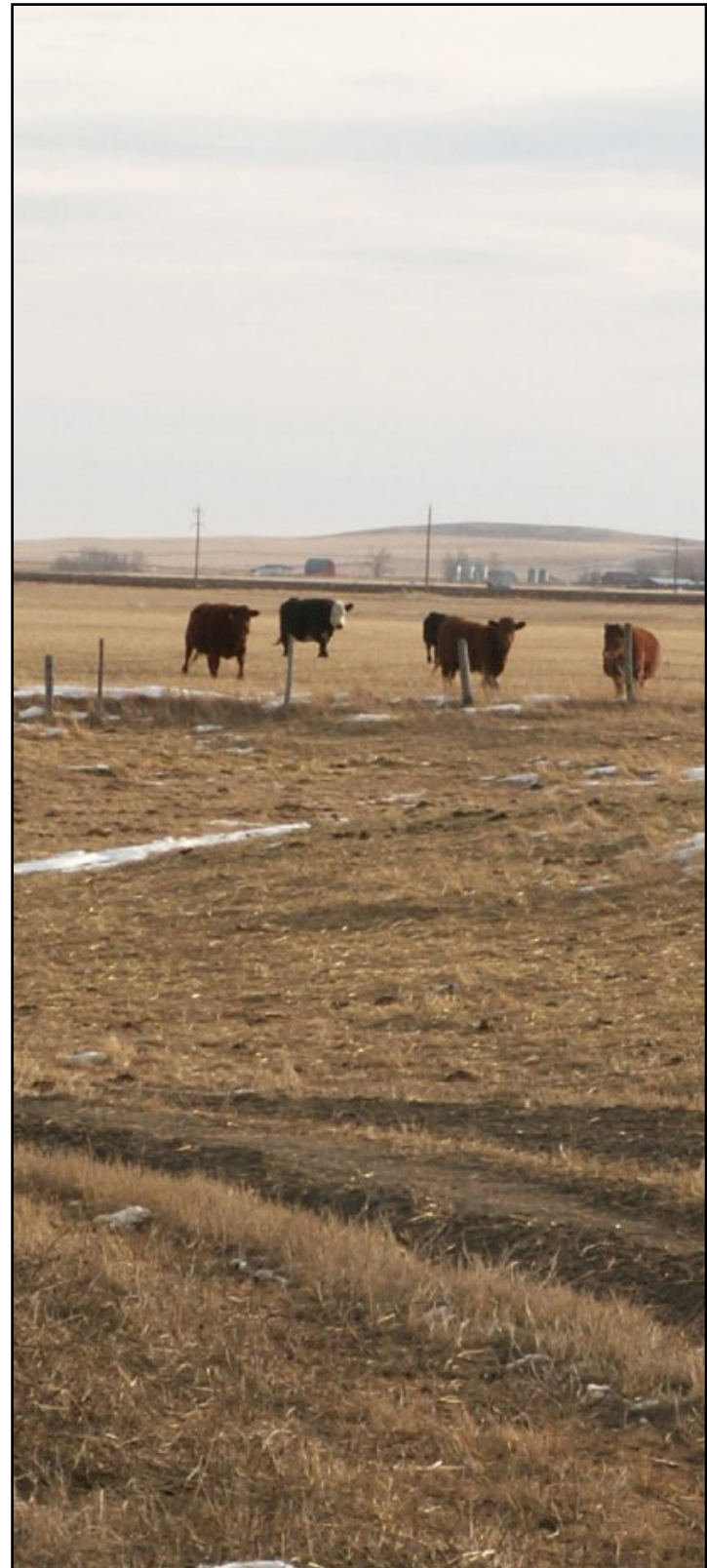
APPLICATION OF THE CEEOT MODEL TO ALBERTA WATERSHEDS

6.1 Introduction

As part of the Alberta Agriculture and Rural Development's (ARD's) Nutrient Beneficial Management Practices Evaluation Project, the application of the Comprehensive Economic and Environmental Optimization Tool (CEEOT) to evaluate beneficial management practices (BMPs) in the Whelp Creek (WHC) and Indianfarm Creek (IFC) watersheds was initiated in 2008. As mentioned in the previous annual progress report (Olson and Kalischuk 2008), the CEEOT model was chosen because of its capabilities in evaluating a wide range of BMPs at the watershed and smaller scales. The CEEOT model activities for the two study watersheds are expected to cover a 4-yr period, ending in March 2011. Detailed CEEOT evaluations of BMPs in the Whelp Creek and Indianfarm Creek watersheds will set the stage for more rapid BMP evaluations for other watersheds in the province.

The primary thrust of the first year of CEEOT activities in the two provincial watersheds was data collection and baseline establishment. While both activities are expected to continue during the next 3 yr, an ambitious effort was made in the current (April 1, 2008 to March 31, 2009) fiscal year (CFY) to obtain the required data and initiate model calibrations for baseline (current) conditions. To streamline the efforts of the 4-yr computer modeling aspect of the project, a protocol document was also produced to serve as a guide for concerted efforts of the entire research team. Accordingly, the following are the specific objectives outlined for the CFY of CEEOT application for BMP evaluations in Alberta:

1. Establish protocol for the application of CEEOT to evaluate BMPs in Alberta watersheds.
2. Collect required data for CEEOT applications in the Whelp Creek and Indianfarm Creek Watersheds and identify gaps in the existing database.



3. Initiate calibration efforts to establish valid baselines for the two study watersheds.
4. Provide training and technical support to ARD staff to ensure their preparedness to apply CEEOT for BMP evaluations in any Alberta watershed by the end of the current project.

The above objectives were further detailed into a number of tasks that were outlined for the research team at the beginning of the project. Timelines and staff from Texas Institute of Applied Environmental Research (TIAER) and ARD assigned to each task were also indicated in the list of activities specified for the CFY. Details of the specific tasks are provided in later sub-sections.

6.2 Overview of CEEOT Modeling System Development

The Comprehensive Economic and Environmental Optimization Tool is a modeling framework (Figure 6.1), which includes economic and environmental modules as well as a policy component. The CEEOT model was developed to facilitate the analysis of environmental issues related to agriculture. The CEEOT program is used to represent the choice of alternative policies or BMPs to enhance environmental quality while fostering a viable agricultural sector in the study region. The CEEOT model was developed as part of a United States Environmental Protection Agency (USEPA) funded project referred to as a National Pilot Project on Livestock and the Environment (NPP; Jones et al. 1993). More details about the CEEOT model were provided in the previous annual progress report (Olson and Kalischuk 2008).

The first computer model implementation of CEEOT was named CEEOT-LP (the L indicating livestock and the P, poultry) because the initial emphasis of application was the livestock industry.

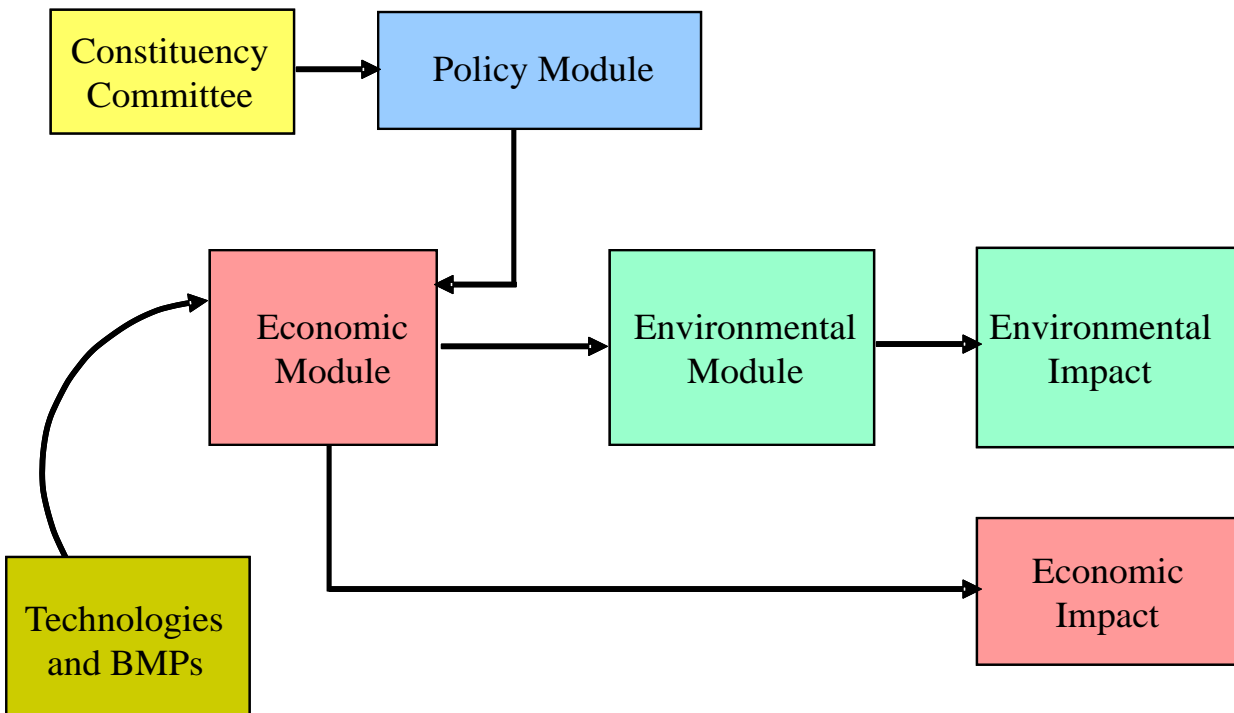


Figure 6.1. Schematic of the CEEOT framework.

As CEEOT applications were extended to various types of watersheds not necessarily dominated by livestock, the “-LP” in the name of the modeling system was occasionally dropped to avoid confusion. When the CEEOT modeling system, particularly the environmental component, was adapted to simulate forestry land uses, the modeling system was on occasion referred to as CEEOT-F (the F standing for forestry).

Farm-level Economic Model (FEM; Osei et al. 2000a) has traditionally been the economic model used in CEEOT applications. Occasionally, Impacts for Planning (IMPLAN; Lindall and Olson 2000), a regional input-output model has been used to extend farm-level economic impacts to the entire economic region of interest. In most computer model implementations of CEEOT, the environmental module has consisted of two simulation models: Agricultural Policy Environmental eXtender (APEX; Williams et al. 2000) and Soil and Water Assessment Tool (SWAT; Arnold et al. 1998). The APEX model is a field-scale simulation model, while SWAT is a watershed-scale model. The APEX model is very useful for situations where detailed definitions of on-farm practices are very pertinent. On the other hand, the relative strengths of SWAT are in incorporating other (nonagricultural) land uses to estimate nutrient and sediment loadings entering a lake or river or even larger water bodies.

More recently, the link between the APEX and SWAT models in CEEOT was automated to enable more efficient and reliable simulation of a variety of practices for large watersheds while still maintaining the precise field-scale BMP simulation capability of APEX. The combined APEX and SWAT models, which constitutes the environmental module of CEEOT, was referred to as SWAT/APEX (Interface) Program (SWAPP; Saleh and Gallego 2007). Consequently, when FEM was linked to the automated APEX/SWAT module, the resulting implementation of CEEOT was often referred to as CEEOT-SWAPP.

In addition to watershed assessments, the CEEOT framework has also been implemented in a macro modeling system for large scale assessments. The large scale modeling system, named CEEOT-Macro Modeling System (CEEOT-MMS; Osei et al. 2003a; 2008b) is particularly useful for BMP evaluations for entire provinces or nations. In CEEOT-MMS, FEM is the economic model and APEX is the sole environmental model. The CEEOT-MMS model is used to evaluate BMPs for large regions by simulating representative farms and using statistically derived weights for each representative farm to aggregate the simulation results to the entire study region or user defined sub-regions.

A summary of past applications of the CEEOT modeling system to evaluate various agricultural and forestry BMPs in various watersheds is shown in Table 6.1. For the sake of simplicity and consistency, computer model implementations of CEEOT for watershed assessments will be referred to simply as CEEOT in the future.

6.3 Summary of Accomplishments for Current Fiscal Year

6.3.1 Protocol Development for BMP Assessment in Alberta

A protocol report for BMP assessment in Alberta was developed in the CFY (Osei et al. 2008a). This report outlines recommended procedures for BMP assessment in Alberta. The procedures outlined in the protocol document for the WHC and IFC watersheds, can be applied to other watersheds in Alberta. The ongoing BMP evaluation project includes field evaluations as well as computer model simulations and analysis. The protocol document covers only the computer simulation and analysis portion of the project. The following are the steps recommended for

Table 6.1. Summary of selected CEEOT applications.

Study area	Subjects of analysis	CEEOT system
Upper North Bosque River Watershed, Texas ^z	Drylot dairies	CEEOT-LP
Lake Fork Reservoir Watershed, Texas ^y	Pasture dairies	CEEOT-LP
Upper Maquoketa River Watershed, Iowa ^x	Multiple livestock and crops	CEEOT-LP
Alto Watershed, Texas ^w	Forestry	CEEOT-F
Duck Creek Watershed, Texas ^y	Broilers and pastured-beef	CEEOT-LP
Mineral Creek Watershed, Iowa ^u	Multiple livestock and crops	CEEOT-LP
Buttrick Creek Watershed, Iowa ^t	Crops	CEEOT-LP
Tipton Creek Watershed, Iowa ^s	Crops	CEEOT-LP
Texas ^r	Animal feeding operations	CEEOT-MMS
Ohio River Basin ^q	Animal feeding operations	CEEOT-MMS
Walnut Creek Watershed, Iowa ^p	Crops	CEEOT-LP

^z Pratt et al. 1997, Osei et al. 2000b, Osei et al. 2003b; ^y McNitt et al. 1999, Osei et al. 2003c; ^x Osei et al. 2000c, Keith et al. 2000;

^w Saleh et al. 2004; ^v Keplinger and Abraham, 2002; ^u Gassman et al. 2003; ^t Osei et al. 2005; ^s Osei et al. 2006b; ^r Osei et al. 2008b; ^q Osei et al. 2006a; ^p Saleh et al. 2007

computer model simulation and analysis of BMPs in any watershed in Alberta.

1. Define problem statement and overall goals of the project, based on the underlying problems and issues.
2. Define scenarios to be evaluated (baseline and alternative scenarios/BMPs).
3. Select appropriate computer models or procure already selected models and other tools required for scenario evaluations.
4. Obtain (collect) required data.
5. Calibrate and verify the models.
6. Perform simulations (of baseline and alternative scenarios/BMPs).
7. Analyze the results (to determine BMP effectiveness).
8. Document findings.

The WHC and IFC watershed assessments entail much more detailed data collection and assessment than is anticipated for most watersheds in the province. However, the detailed assessments that are being performed in the two study watersheds will provide necessary insight into how the more rapid and less intensive evaluations can be carried out in other Alberta watersheds. A subsequent report will provide a more detailed discussion of transferability of the WHC and IFC watershed assessments to other watersheds in Alberta.

6.3.2 Preparation of GIS Format Input Files

6.3.2.1 Topographical Data

Digital Elevation Model (DEM) data were obtained for IFC Watershed based on 25-m and 1-m grid resolution. The 25-m grid DEM represents ground surface topology or relief at a scale of 1:20 000, and it has relative horizontal and vertical accuracy (depending on terrain) of +/- 5 and +/- 3 m, respectively. The data were prepared by Alberta Environment in 2001 using the NAD83-10TM projection. Also, a 1-m grid DEM was obtained for the IFC Watershed. The data were derived using remote sensing technologies called Light Detection and Ranging (LiDAR), and it has relative accuracy of +/- 0.3 m. For the WHC Watershed, only a 25-m DEM was obtained since the

1-m DEM was not available. In the future, plans are to acquire a more detailed DEM based on LiDAR or Global Positioning System (GPS) technologies. As of December 2008, the 25-m DEM data were used to prepare SWAT input files for both watersheds (Figures 6.2a and 6.3a). The process involved application of a Geographical Information System (GIS) extension called AvSWAT (Di Luzio et al. 2002) to estimate landscape characteristics such as sub-watershed boundaries, fields slope length and steepness, and channel steepness.

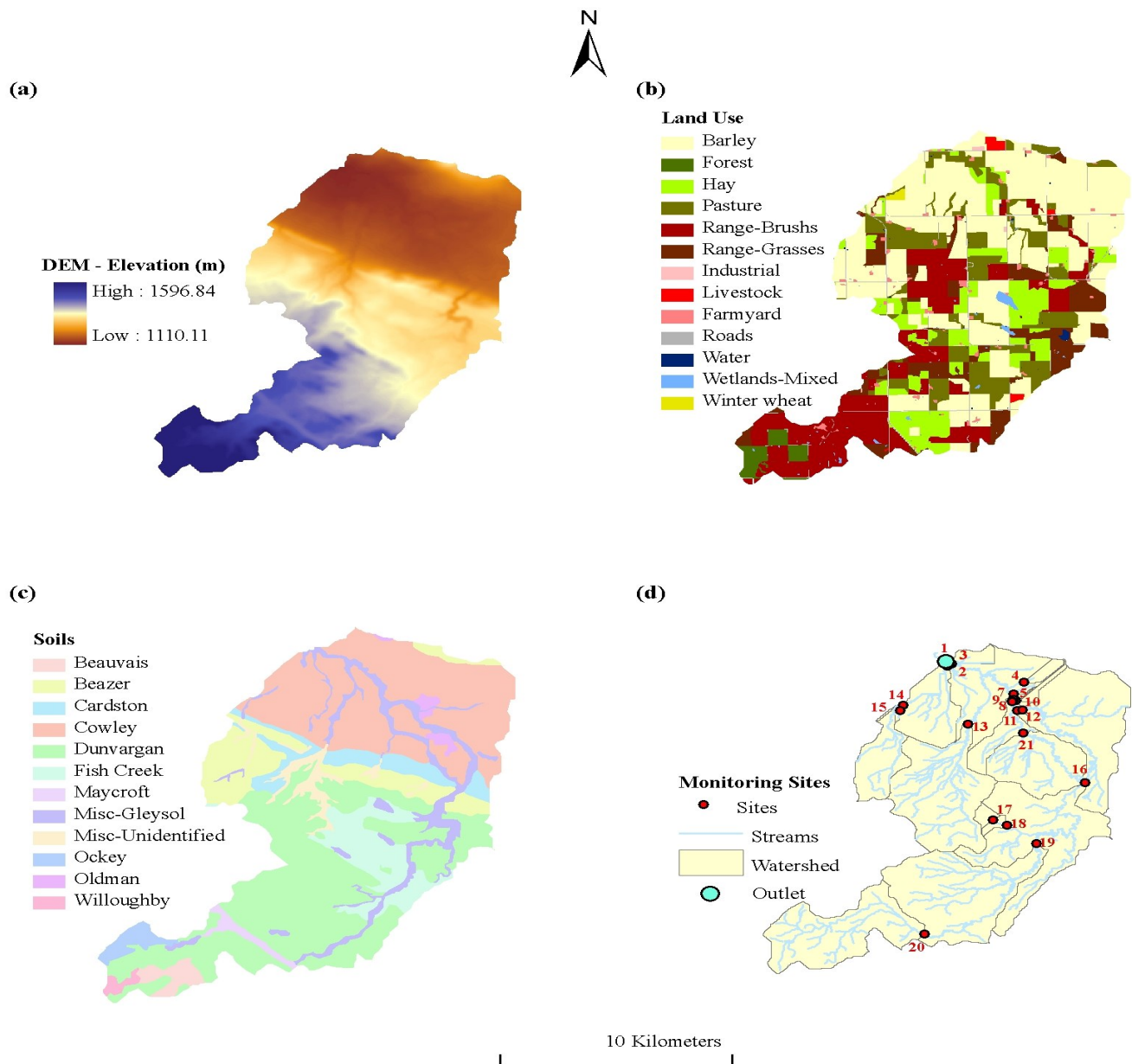


Figure 6.2. Maps of Indianfarm Creek Watershed showing: (a) Digital Elevation Model, (b) land use, (c) soils, and (d) monitoring sites.

6.3.2.2 Land Management

Ortho image and county maps were used to initially outline polygon boundaries of unique land uses within the IFC and WHC watersheds. In total, 431 and 774 polygons were identified in IFC and WHC Watersheds, respectively (Figures 6.2b and 6.3b). In addition, the following land management data were collected: (1) type of vegetation cover on each polygon, (2) schedule of field operations on selected farms, and (3) information on livestock inventories. The collected data are discussed in more detail in the previous annual progress report (Olson and Kalischuk 2008) and Sections 2 and 3 of this report. The management data were assembled first into a tabulate format, and then Visual Basic scripts were used to convert them into SWAT and APEX format input files.

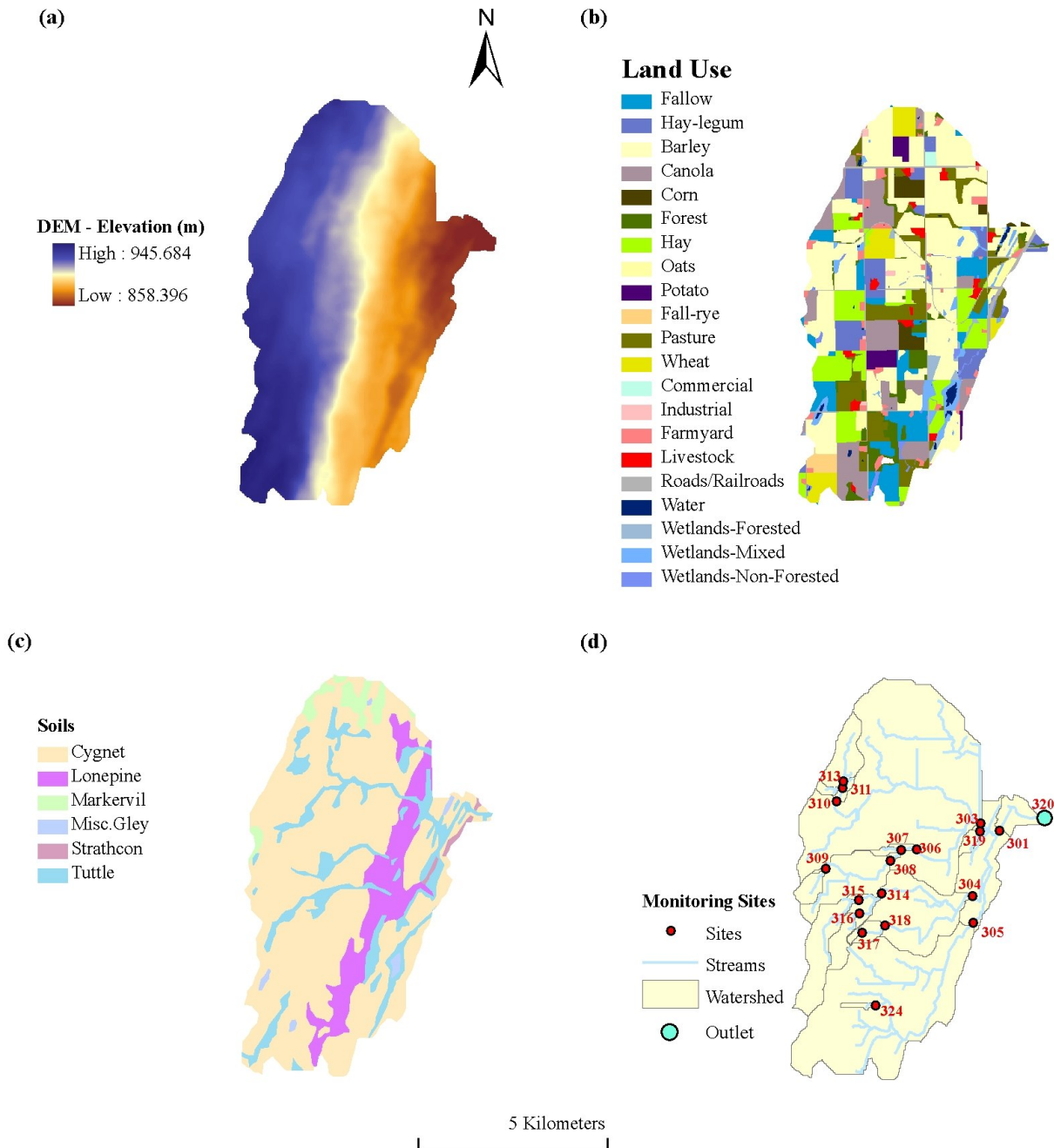


Figure 6.3. Maps of Whelp Creek Sub-watershed showing: (a) Digital Elevation Model, (b) land use, (c) soils, and (d) monitoring sites.

6.3.2.3 Distribution of Soil Name Series

The Agricultural Region of Alberta Soil Inventory Database (AGRASID) represents the most accessible, digital format soils information (Alberta Soil Information Centre 2001) in Alberta. The data describes the distribution of soils within the agricultural areas of Alberta at an intended scale of representation of 1:100 000. In the database, there are over a thousand soil name series and each of them lists soil properties for up to nine layers to maximum depth of 1.2 m. In addition, each soil polygon provides information on proportional distribution of soil series; however, there is no information on their geographical location within polygons. Brierley and Bock (2008) developed a method to modify AGRASID information and the distribution of soil series are displayed at a scale of 1:30 000 (Figures 6.2c and 6.3c; Tables 6.2 and 6.3).

6.3.2.4 Hydrographic Data

Location of existing water bodies and ephemeral streams is represented by hydrographic data. The data were obtained from Alberta Environment (Figures 6.2d and 6.3d), and were used with the DEM data in the AvSWAT program to help simulate the appropriate location of streams and water bodies.

Table 6.2. Distribution of soils in Indianfarm Creek Watershed.

Soil name	Area (ha)	Percentage (%)
Beauvais	237.5	1.7
Beazer	1,384.6	9.6
Cardston	693.9	4.8
Cowley	3,918.1	27.2
Dunvargan	4,966.4	34.5
Fish Creek	1,044.8	7.3
Maycroft	157.1	1.1
Misc-Gleysol	1,155.6	8.0
Misc-unidentified	403.3	2.8
Ockey	229.5	1.6
Oldman	137.9	1.0
Willoughby	79.7	0.6
Total area	14,408.2	100.0

Table 6.3. Distribution of soil types in Whelp Creek Watershed.

Soil name	Area (ha)	Percentage (%)
Cygnnet	3,021.5	69.2
Lonepine	531.9	12.2
Markerville	130.8	3.0
Misc.Gleysol	34.2	0.8
Strathcona	25.2	0.6
Tuttle	620.4	14.2
Total Area	4,364.0	100.0

6.3.2.5 Location of Monitoring Stations

A GPS survey was conducted to map locations of all monitoring stations in each watershed. In total, 20 and 19 locations were surveyed at IFC and WHC watersheds, respectively (Figures 6.2d and 6.3d). The data were also used in the AvSWAT analyzes to delineate the contributing drainage area to each monitoring station, and to define the area's typical landscape characteristics.

6.3.3 Development of Table Format Input Files

6.3.3.1 Climate Data

Daily input files. The SWAT and APEX climate input files require daily precipitation, maximum and minimum temperature, solar radiation, wind speed, and relative humidity data. For this project, historical data for the period of 1971 to 2005 were estimated for all townships enclosed within the IFC and WHC Watersheds using the observed data from adjacent climate stations and an extrapolation procedure developed under the Soil Quality Program (Shen et al. 2000). In the procedure, the above mentioned weather parameters, with the exception of precipitation, were plotted onto a township network of grid points and then the average values were calculated inside polygons. The interpolation of precipitation values was based on a hybrid method, which combined inverse-distance weight and nearest-station assignment. The extrapolation method was able to predict the number of precipitation days per month and total daily precipitation amount reasonably well. It is expected that this data file will be used to conduct long-term simulations for both watersheds.

In addition, the observed temperature, relative humidity, and precipitation (rain and snow) data were acquired in 2008 from IFC (IWS1, IWS2, IWS3, and IWS4 stations) and from WHC (WWS1 and WWS2 stations) watersheds. Due to lack of data availability prior to the 2008 period at these stations, additional data were obtained for the 2000 to 2007 period from Pincher Creek and Lacombe CDA weather stations. Sections 2.2 and 3.2 of this report discuss the IFC and WHC weather stations in greater detail. It is expected that these data will be used to calibrate the model for both watersheds.

Weather generator input files. The SWAT and APEX weather generator routines require calculation of average monthly values of observed climate data (Neitsch et al. 2005). The weather generator program would estimate all daily weather parameters (e.g., precipitation) for any time period. In Alberta, the statistical data were prepared for 18 stations in a previous study, and were adopted to estimate missing values needed in short- and long-term simulations (Table 6.4).

6.3.3.2 Soil Physical and Chemical Characteristics

Soil physical characteristics. The soil-physical parameters have a major impact on predicted movement of water and air within a soil profile and predicted water balance within a hydrologic response unit (HRU). A list of soil physical properties and a brief description of the methods used to calculate these values for SWAT and APEX are shown in Table 6.5.

Soil chemical characteristics. To initiate simulations, SWAT and APEX require initial concentrations of nitrate nitrogen ($\text{NO}_3\text{-N}$), organic N (ON), water soluble P (WSP), and organic P (OP) for all soil layers. Generally, WSP is not readily available because soil test P (STP) data are more commonly used. In the BMP study, soil samples were collected from the 0- to 15-cm depth

Table 6.4. List of Alberta climate stations with available data to prepare weather generator input files.

Station name	Latitude (degrees)	Longitude (degrees)	Elevation (m)	Years of data	Start year	End year	Soil zone
High Level A	58.37	117.10	338.3	17	na ^z	na	Dark Grey
Peace River A	56.14	117.26	570.9	25	1965	1989	Dark Grey
Beaverlodge CDA	55.12	119.24	691.7	30	1960	1989	Dark Grey
Grande Prairie A	55.11	118.53	669.0	22	1968	1989	Dark Grey
Edson A	53.35	116.28	925.4	20	1970	1989	Grey
Cold Lake A	54.25	110.17	541.0	24	1966	1989	Dark Grey
Edmonton Namao A	53.40	113.28	687.6	26	1964	1989	Black
Vegreville CDA	53.29	112.02	635.8	18	1971	1988	Black
Lacombe CDA	52.28	113.45	847.3	22	1963	1984	Black
Coronation A	52.04	111.27	791.0	14	1976	1989	Dark Brown
Lethbridge A	49.38	112.48	928.7	30	1960	1989	Dark Brown
Calgary Int'l A	51.02	114.04	990.5	30	1960	1989	Black
Pincher Creek	49.30	113.57	1155.2	15	1965	1979	Black
Brooks AHRC	50.33	111.51	703.8	24	1964	1987	Brown
Medicine Hat A	50.01	110.43	716.9	20	1970	1989	Brown
Vauxshall CDA	50.03	112.08	778.8	28	1960	1987	Brown
Manyberries CDA	49.07	110.28	934.2	21	1964	1984	Brown

^z Not available.

on selected sites to measure NO₃-N, ammonium nitrogen (NH₄-N), and STP concentrations. The STP content was tested using the Modified Kelowna (MK) method (Qian et al., 1991). More detailed information on soil sampling is available in the previous annual progress report (Olson and Kalischuk 2008).

Another study (Wright et al. 2003) showed that there is a linear correlation ($y = 0.84x - 16$, $r^2 = 0.99$) between results from MK and Mehlich 3 methods for STP. To derive the WSP values, first the MK STP values will be recalculated to be comparable with the Mehlich 3 STP values, and then an algorithm described by McFarland (2006) will be used to estimate WSP based on the Mehlich 3 STP values.

6.3.3.3 Measured Water Quantity and Quality

As of December 2008, 2 yr of flow and water quality data were available for the IFC Watershed. However, only 1 yr of flow and water quality data were available for the WHC Sub-watershed. The data were discussed in more detail in the previous annual progress report (Olson and Kalischuk 2008) and Sub-sections 2.4 and 3.4 of this report. The available data from both watersheds will be used for the initial SWAT and APEX testing and calibration process.

6.3.3.4 Economic

As of December 2008, price data on most farm inputs and outputs had already been collected by ARD staff and are available for FEM simulations. Specific price and other data received from Alberta sources are shown in Table 6.6. Additional data requirements are being assessed. In

Table 6.5. Sources of soil physical properties for provincial watersheds.

Parameter	Definition	Data source for Alberta
HYDGRP	Soil Hydrologic Group - part of U.S. Soil Conservation Service Curve Number (SCS-CN) method that describes relationship between rainfall and runoff under given soil and land cover conditions. The SCS method identifies four hydrological soil groups (A, B, C, D) based on soil permeability.	The grouping was assumed based on the saturated hydraulic conductivity (K) of most restrictive layer to a depth of 1.0 m using the following grouping criteria: A for $K > 254 \text{ mm h}^{-1}$, B for K ranging between 84 and 254 mm h^{-1} , C for K ranging between 8.4 and 84 mm h^{-1} , and D for $K < 8.4 \text{ mm h}^{-1}$
Sol_ZMX	Maximum rooting depth of soil profile	Assumed the same as the entire depth of soil profile
ANION_EXCL	Fraction of porosity from which anions are excluded	Assumed default 0.50
SOL_CRK	Potential crack volume of the soil profile	Assumed 0.50 ($\text{m}^3 \text{ m}^{-3}$)
TEXTURE	Texture of soil layer	AGRASID database
SOL_Z	Depth from soil surface to bottom of layer	AGRASID database
SOL_BD	Moist bulk density	AGRASID soil texture data and Saxton and Willey (2005) equations ^z
SOL_AWC	Available water capacity of the soil layer	$\text{AWC} = \text{FC} - \text{WP}$
FC	Water content at field capacity	AGRASID soil texture data and Saxton and Willey (2005) equations
WP	Water content at permanent wilting point	AGRASID soil texture data and Saxton and Willey (2005) equations
SOL_K	Saturated hydraulic conductivity	AGRASID soil texture data and Saxton and Willey (2005) equations
SOL_CBN	Organic carbon content	AGRASID data
CLAY	Clay content	AGRASID data
SILT	Silt content	AGRASID data
SAND	Sand content	AGRASID data
ROCK	Rock fragment content	AGRASID data
SOL_ALB	Moist soil albedo	$\text{SOL_ALB} = (0.7 / (\text{Exp}(0.5596 * \text{OM})))^2$ Where: $\text{OM} = \text{SOL_CBN} * 1.724$
USLE_K	USLE equation soil erodibility (K) factor	Williams (1995) equations

^z The performance of the Saxton and Willey (2005) equations was evaluated by comparing the predicted SOL_BD, FC, and WP values (Table 6.7) with the measured values. The comparison of 55 soil records obtain from 40 different soil quality benchmark sites yielded r^2 of 0.66, 0.60, and 0.78 for SOL_BD, FC, and WP, respectively.

Table 6.6. Economic data obtained from Alberta as of December 2008.

Data	Source ^z
Regional crop area distribution	ARD, Statistics Canada
Farm input prices	ARD
Farm product prices – crop and forage	ARD, AFSC, CWB
Crop yields	AFSC, Statistics Canada, AGC, ARD
Cost and returns estimates – crop, forage, livestock	ARD (AgriProfit\$)
Ammonia volatilization losses by manure application type	ARD
Manure production characteristics	ARD
Crop agronomic requirements	ARD

^z AFSC = Alberta Financial Services Corporation, AGC = Alberta Grain Commission, ARD = Alberta Agriculture and Rural Development, CWB = Canadian Wheat Board.

addition, farm management data, which were key components of the data required for economic model simulations, have been obtained through ongoing producer surveys initiated during the early part of 2008.

Representative farms to be simulated in FEM have been set up and calibration of FEM for the two watersheds has been initiated in the CFY. Information used to define representative farms is based on the current distribution of farms in the two watersheds as well as field management information obtained from the watershed through producer surveys conducted in 2008. Representative farms include a set of crop and livestock operations that mimic the general distribution of farms in the WHC and IFC watersheds.

The objective of representative farm definition is to mimic the distribution of farms in two watersheds, without recourse to simulating each individual farm. However, FEM provides the capability to include as much detailed farm-level information as desired. The information used in defining each of the representative farms will include the data categories listed below.

- Land area farmed – owned and leased
- Cropping systems
- Field operations
- Crop nutrient contents
- Livestock nutrient requirements
- Livestock inventory
- Manure production characteristics
- Equipment inventory
- Manure handling options
- Farm structures and facilities
- Farm lending and borrowing terms
- Farm input and output prices

During simulation of the baseline and alternative scenarios, any changes in management practices at the farm level for a given scenario (e.g., changes in manure application rates and timing) will be conveyed to FEM through the CEEOT interface program. It is expected that these changes will have environmental and economic impacts. The CEEOT interface will convey the results obtained from SWAT and APEX simulations (e.g., sediment and nutrient loadings) to FEM as well as to where FEM will evaluate the economic impacts of changes in these environmental factors (e.g., sediment and nutrient loadings).

6.3.4 Gaps and Limitations in the Existing Database

The Protocol for BMP Assessment document (Osei et al. 2008a) contains a comprehensive list of the data requirements for using computer modeling systems, particularly CEEOT, to evaluate the economic and environmental impacts of BMPs. The protocol document also discussed current data gaps and how to address them.

For the most part, data items indicated in Osei et al. (2008a) as minimum requirements are available. However, data acquisition efforts are ongoing and additional data are anticipated in the next (April 1, 2009 to March 31, 2010) NFY to meet each of the data requirements. The following are the gaps and limitations in the existing data as of the end of December 2008.

6.3.4.1 Data Gaps

The following data are incomplete as of the end of the 2008 calendar year. Efforts are ongoing to bridge these data gaps as quickly as possible. Some of these data gaps will be fully addressed by the end of the CFY. Any remaining data gaps as of the end of the CFY will be bridged early in the NFY, in time for model calibrations to be completed on schedule.

- Feed nutrient contents – dry matter and composition of various feeds
- Livestock inventory – number and types of livestock species
- Livestock operations – livestock husbandry activities
- Nutrient requirements
- Proportions of manure handled in solid or liquid form or directly deposited on pasture
- Differences in characteristics of solid and liquid manure and directly deposited manure
- Manure management (handling) options
- Impacts of manure management (handling) options
- Plant availability of manure nutrients
- Farm structures and facilities
- Farm equipment characteristics (speed, width, field efficiency, etc.)
- Ponds, wetlands, and reservoirs water storage capacity

Additional data will be collected for all variables where data gaps are noted, i.e., variables for which available data are indicated above (and in the protocol document) as incomplete. In the event that the required data is unavailable, the most reliable proxy or alternative source will be used, as indicated in the protocol document. For instance, if specific weather data are unavailable for one of the two study watersheds, the missing data will be approximated using historic weather statistics or data from a nearby weather station. The protocol document (Osei et al. 2008a) also contains additional detail on how each data limitation or gap will be addressed.

6.3.4.2 Data Limitations

Data that have been obtained on the following variables is adequate for model calibration efforts to proceed. However, additional information on these data items is anticipated in future years. Consequently, CEEOT applications using current values for these variables will be limited as any calibrations or simulations may need to be redone in light of additional data.

- Cropping systems – crop rotation pattern
- Crop operations – field operations for each crop
- Equipment used in crop operations
- Crop yields
- Manure production characteristics
- Manure application rates on various land uses

For instance, cropping systems have been deduced based on information contained in producer surveys and other available data from the watershed. However, additional data in subsequent years may reveal slightly different crop rotations than initially anticipated. The same limitation applies to crop yields. Additional data will give better indication of baseline crop yields and yields under each of the alternative scenarios.

6.3.5 CEEOT Simulation Activities

The CEEOT simulation efforts in 2008-2009 focused on data acquisition and providing training to ARD staff to enable them to use the CEEOT tool effectively to evaluate BMPs in any provincial watersheds. In addition, the model calibration and verification process for the WHC and IFC watersheds was initiated.

Fourteen farm surveys for Indianfarm Creek and 27 farm surveys for Whelp Creek were used to generate a total of 41 representative farms for the two watersheds. Survey information included crop histories and crop yields, livestock and equipment inventories, and field operations. The equipment database in FEM was upgraded to include all the machinery listed in the farm surveys. Representative farm information includes all farm specifications required for holistic assessment of each farm. Information not available from the surveys (such as crop nutrient contents, livestock nutrient requirements, and manure production characteristics) are being derived from published data that is applicable to farms in Alberta. No economic simulation results are available for the CFY as economic model calibrations have not yet been completed.

A separate set of SWAT input files have been prepared for the WHC and IFC Watersheds. Initial SWAT simulations were conducted for both watersheds; however, the simulation results are not presented due to limited input data at this time. The SWAT calibration process will continue during the remaining part of CFY, as soon as more input data become available.

6.4 Activities Planned for Fiscal Year 2009-2010

The following activities are planned for NFY in order to ensure successful completion of BMP evaluations in the WHC and IFC watersheds using the CEEOT modeling system. Some of the tasks listed below are continuation of tasks initiated in CFY. For instance, calibration and baseline establishment efforts will not be completed until data on certain variables, e.g., management practices, have been collected for at least another fiscal year.

Calibrate the environmental models and conduct simulations within CEEOT for the two selected Alberta watersheds, and evaluate the environmental impacts of the monitored BMPs in those watersheds.

The CEEOT model will be used to estimate the economic and environmental (water quality) impacts of the BMPs included in field evaluations. As indicated in the 2008 progress report (Olson and Kalischuk 2008), the following BMPs are under consideration for IFC (Table 6.7) and WHC (Table 6.8) watersheds.

In addition, the following scenarios are being considered for CEEOT model simulations in order to provide more insight into the effectiveness of individual BMPs and combinations of practices. The final list of BMPs to be simulated will be determined after consultation with stakeholders in the watershed and ARD staff.

1. Cessation of manure application on frozen ground in winter
2. Exclusion of cattle from riparian areas
3. Reduction of manure application from crop N uptake rate to crop P uptake rate
4. Constructed wetlands
5. Fencing and intensive rotational grazing
6. Manure incorporation

Table 6.7. Indianfarm Creek Watershed beneficial management practices.	
BMP site	Specific BMP components implemented or considered for this site
Impoundment	Restriction of cattle access to impoundment Provision of off-stream watering Re-establishment of vegetative ground cover in riparian zone
North Manure Field	Setback zones from drainage channel Timing and mode of manure application
Corral and Pasture	Improved corral structures Removal of manure pack Re-vegetation of denuded areas Restriction of livestock access to creek Provision of off-stream watering
Wintering	Relocation of wintering site away from creek Planting of vegetation (grass) in critical area Restriction of cattle access to creek
South Manure Field	Change in timing and mode of manure application Setback zones from drainage channel
Dairy Manure Field	Changes in rate, timing, and mode of manure application Improved manure storage

Table 6.8. Whelp Creek Sub-watershed beneficial management practices.	
BMP site	Specific BMP components implemented or considered for this site
West Field	Nutrient management – rates, timing, mode
North Field	Nutrient management – rates, timing, mode
East Field	Nutrient management – rates, timing, mode
South Field	Nutrient management – rates, timing, mode
South Pasture	Control of cattle access to creek Creek bank stabilization? Nutrient management – stocking density Grazing management