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Simulating the land-use impact of municipal planning policies and stakeholders' goals in a residential land development project in southern Alberta using an agent-based model

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by

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Simulating the land-use impact of municipal planning policies and stakeholders' goals in a residential land development project in southern Alberta using an agent-based model

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Abstract

The objective of this research is to study the influence of land development regulations and stakeholders' goals on land-use resources in Southern Alberta. An agent-based model was developed to simulate the decision-making process of the developer, the citizens, and the town authorities in the planning of a residential land development in Strathmore, Alberta. Information on the decision-making process was collected through publicly available documents and interviews with the stakeholders and was compiled in terms of their goals and the regulations influencing their decisions. Several land development scenarios were simulated over a ten year period. The model generates a land-use map showing the change in the environment based on the agents' goals and their decisions. The model results were validated by comparing them with actual published documents and assessment by the stakeholders. The results illustrate that the model could be a valuable tool to better understand the relationship between stakeholders' goals and regulations on land-use change.

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And last but not least to you, the reader; thank you for taking the time to read my thesis.

I encourage everyone to please consider the planet before printing this thesis.

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Chapter One: Introduction

This chapter is separated into six sections. The first section presents the context of the study; the broad issues regarding population growth and urban expansion and how they relate to infrastructure development in residential subdivision and urban growth in Southern Alberta are discussed. This is done using the City of Calgary and the smaller outlying Town of Strathmore as examples. The second section details the Land-use Redesignation and Outline Plan application process involving a complex regulatory path and the input and decision making of many stakeholders that a land developer must follow. The third section discusses modelling and looks at the types of models and their properties with an emphasis on simulation models. The fourth section explores previous research involving agent-based models that simulate complex systems similar to the land development planning process. The fifth section introduces the objective of this research and the sixth section outlines the organization of the thesis.

1.1 Context of the study

Like most urban centers in North America, the City of Calgary has been experiencing steady population growth over the past six decades, from the strong Alberta economy, natural increase, and net migration (City of Calgary 2009). This growth has been portrayed in a chart labelled “Calgary’s Growing Population” with decade increments since 1951 from the Applied Research History Group at the University of Calgary. The chart shows a 93% population explosion from 1951 to 1961 of 129,060 to 249,641 inhabitants respectively. Since then, the population has grown by approximately 35% per decade to the current population of 1,043,000 inhabitants (Applied History Research Group 1997-2001; City of Calgary 2008).

Calgary has also been experiencing unprecedented land-cover growth over the same time period. The "History of Annexation" map produced by the City of Calgary (2007) reveals a 276% growth in land area between 1951 and 1961 of 104 to 392 km^2. Since then the gross area has grown by 14% per decade to the current area of 745 km^2 (City of Calgary 2007). This equates to densities of 1400 inhabitants or 518 housing units per gross km^2 (2.1 housing units/acre). Removing the areas allocated for future growth, landfills, industry, water, regional parks and the Calgary Ring Road transportation/utility corridor, the net or current built area is 326 km^2 (City of Calgary 2007). This improves the density numbers to 3200 inhabitants or 1185 units per net km^2 (4.8 housing units/acre or 11 units/hectare), considered low density (Haughton & Hunter 2003). The large difference between the gross and net development areas and the residential land developments currently expanding at the periphery, still pushing the city limits, add up to a sprawling city with over 50% vacant land.

Such population growth is not accommodated for by the simple annexation of more land to expand the City of Calgary. There are environmental, social and economic problems not only in the City of Calgary but also in the surrounding cities, towns, villages and municipalities that must be taken into consideration. Some of these problems include:

- increased demand on and cost for resources, including land and water;
- increased intensity of use on and competition for land;
- change in settlement patterns;
- increased interaction, and conflict or required cooperation with adjacent municipalities;
- increased demand on existing infrastructure, including: roads, utility distribution, collection and treatment facilities;
- increased cost for new infrastructure, including: roads, utilities, schools, and other community facilities;
- increased environmental ground, water and air pollution; and
- increased health and emergency costs.

Some of these costs can be avoided; some cannot, but most can be reduced.

In his book, “Expansive Discourses: Urban Sprawl in Calgary, 1945-1978”, Foran (2009) stresses the responsibility of underground utilities installation in determining the physical growth patterns of the City of Calgary. He states that labyrinth of pipes managing storm water runoff, disposing of wastewater and supplying potable water to every dwelling in the City of Calgary were more important that any other infrastructure in shaping the physical growth of the City. Until 1954 the City of Calgary was responsible for planning, designing and constructing all residential subdivision infrastructures within the City, and did so based on its own capacity and existing trunk capacity. During the population boom in the 1950's, the City did not have the staff to keep up with the demand. In 1954 the City of Calgary made a decision to hand over their responsibilities to private enterprises giving them the job of providing and paying for the construction of this infrastructure. This decision basically gave control of residential development and growth of the City to the developers. From 1954 onward, the costs associated with the construction of new infrastructure accrued by the developers were passed down to new home buyers. The cost of a modest suburban bungalow in 1960 was $12,000; in 1970 it was $20,000, a 66% increase, and in 1980 it was $70,000, a 250% increase. Since then, housing prices have increased approximately 81% per decade to the current average house price of $417,000. Once the new infrastructure was constructed, its ownership would be handed over to the City as public utilities, becoming the responsibility of the City to maintain. The costs associated with increased demand on existing infrastructure and the maintenance of new infrastructure was passed down from the City to its tax payers.

The City of Calgary's "Population Picture", 2008, predicts a population of 1.6 million by 2037 and just fewer than two million inhabitants by the 22nd century (City of Calgary 2009), an increase of approximately 18% per decade. If these population predictions are correct and planning and land development decisions continue to be made based on current planning policy and developer self interest, the City of Calgary will continue to expand and costs will continue to climb.

The Town of Strathmore, established in 1883 by the Canadian Pacific Railway, is located at about 40 km east of Calgary on the Trans-Canada Highway (Figure 1). It currently has a population of 11,335 inhabitants and covers approximately 15.5 km^2 (Brown and Associates Planning Group 2008). The Town of Strathmore has been experiencing some of the impacts of the growth of the City of Calgary. As the competition for land within the City of Calgary increases, so does the cost for land. This tends to force young families unable to afford a house in the city to purchase outside of the city and commute to their place of employment, or retirees wanting to get away from the city to move out to the country. It also creates demands on the Town of Strathmore to accommodate this net migration. As a consultant to the Town of Strathmore, Brown and Associates Planning Group (2008) published the "Town of Strathmore Growth Study" that predicts a population of 56,731 inhabitants by 2056 to cover approximately 26.8 km^2, an increase of approximately 38% in population and 12% in area per decade.

Figure 1: Location of Calgary and Strathmore in southern Alberta

Like many cities and towns surrounding the City of Calgary, the Town of Strathmore has implemented planning regulations, land development policies and infrastructure design standards very similar to those of the City of Calgary. In creating a new residential development, a land developer balances the construction cost associated with building the infrastructure and constructing the home with its market value, passing the cost of the construction of new infrastructure to the new home purchasers. The costs associated with resizing existing infrastructure and the maintenance of new infrastructure are passed on to the property tax payers.

In order to alleviate the problems associated with this growth, the Town of Strathmore and the City of Calgary have joined an organization called the Calgary Regional Partnership (CRP), which includes 19 municipalities in the region. The CRP is currently drafting a regional plan that intends to guide future regional growth around Calgary. New growth will be around existing centres to ensure efficient use and maintenance of infrastructure, the preservation of agricultural lands, and environmental sustainability. The regional plan will follow the Alberta Land-use Framework, a strategy laid out by the Province of Alberta to manage growth, development, and land-use activities in the province that emphasizes cooperative regional land use and resource planning (Calgary Regional Partnership 2009).

The facts regarding the population, urban expansion and housing cost stated above for both the City of Calgary and the Town of Strathmore bring several questions to mind:

- Who is making the planning policy decisions?
- What are the goals and objectives of the decision makers?
- How are the decisions makers interacting when making their decisions?
- Do the decision makers know the impact of their decisions?
- Do the decision makers have the tools to: 1) predict the future impact of their decisions should they continue making similar decisions, and 2), predict the future impact of their decisions if they were to change their goals?

Municipal and inter-municipal planners use various methods and tools to create a municipal plan that best suits the ideals, values and vision of the community in terms of future social need, economic feasibility, and environmental sustainability. These methods include forecasting based on present conditions using historical data, past success and failures. Some of the tools include statistical analyses of census data, and community economic models that attempt to predict the increase or decrease in population based on industry and the employment created. Political influence aside, the growth plans and planning policy developed for a municipality set the direction of the community growth, which may leave limited choice for developers and citizens. The whole development process is an intricate system and one which planners attempt to envision. One of the outcomes, which is the focus of this research, is a decision that changes land use allowing for development to occur on a particular parcel of land. Despite the array of methods and tools available, these decisions are still quite often made in the face of uncertainty. The rapidly expanding region of Calgary in Southern Alberta is a perfect example of such a situation.

The central issue addressed here is that provincial, municipal, and urban and town planners have a limited, although improving, ability to forecast the cumulative effect of many individual decisions made by stakeholders having different goals on the overall environment over which they make their decisions. They need a tool that can model how environmental patterns and trends emerge from the intricate interactions and complex behaviour of several stakeholder groups who might have conflicting goals and views. Having access to such a tool would enable environmental impact forecasting of current goals, decisions and policies, and would allow stakeholders to perhaps modify their goals and analyze possible future impact before the implementation of their decisions.

1.2 Planning and land development

This section touches on land use and discusses the general planning process adhered to throughout Alberta when changing land use to allow for development. It is within this process that the majority of municipal planning policy is applied.

The developed area allocated for residential purposes is by far the largest portion of any urban center. This allocation of area for a particular use is called land use. Types of land use include: residential (single/multi-family), commercial/retail, mixed use, industrial (light/heavy), public utility, and reserve (urban/environmental/municipal). The role of a land use on a parcel of land is to identify the legal control on the use and intensity of development permitted on the land.

The development of a parcel or parcels of land, for residential purposes, requires the planning of the physical and legal changes to the land. The physical changes include designing the size and configuration of the proposed site infrastructure such as: site grading, road design, storm water control system, and the servicing of water, sanitary sewer, electrical, communication and gas utilities. In Alberta, the documents regulating the legal changes include subdivision and land-use redesignation. Land-use is regulated through the following documents in hierarchical order: the Alberta Municipal Government Act (MGA), the Inter-Municipal Plan (IMP), the Municipal Development Plan (MDP), planning documents of the municipality, Land-use Bylaw, and Land-use (LU) Redesignation (Figure 2).

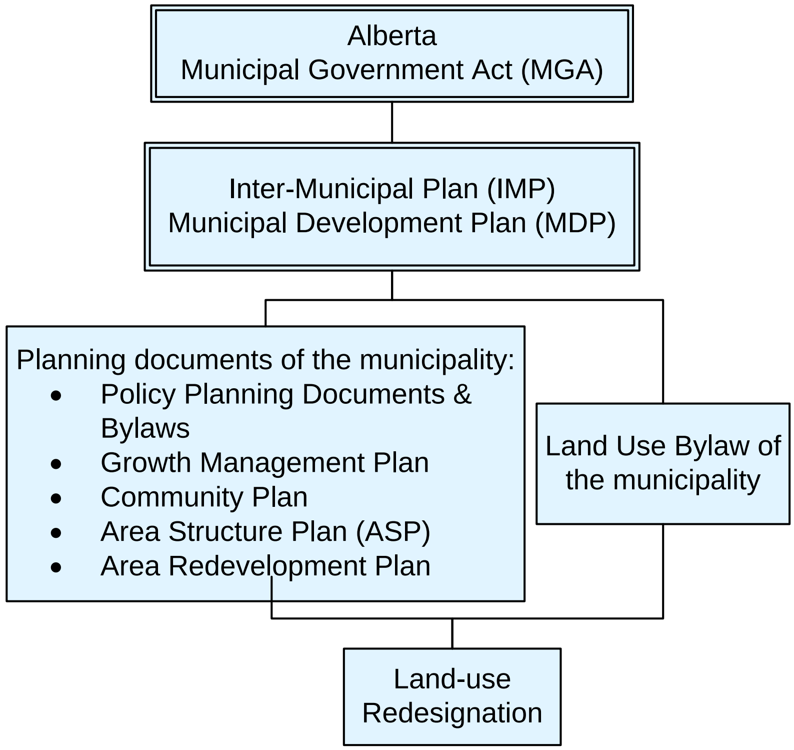

Figure 2: Hierarchy of planning documents regulating land use in Alberta

The Alberta Municipal Government Act (MGA) governs municipal planning in Alberta. Section 617 of the Act states that its purpose is "to provide means whereby plans and related matters may be prepared and adopted to achieve the orderly, economical and beneficial development, use of land and patterns of human settlement, and to maintain and improve the quality of the physical environment within which patterns of human settlement are situated in Alberta without infringing on the rights of individuals for any public interest except to the extent that is necessary for the overall greater public interest" (Government of Alberta 2000).

Within the MGA, the hierarchy of plans that provide guidelines for the use of land is established, the planning authorities in the province that implement these plans are identified, and statutory guidelines about how planning authorities administer the use of land at a local level are provided including procedures in decision making, and policy preparation and implementation.

The Inter-Municipal Plan (IMP) and the Municipal Development Plan (MDP) are the first and second most senior plans, respectively, regarding the use of land according to the plan hierarchy in the MGA. An IMP must address the administrative provisions for municipalities that adopted the plan and the procedures on how to amend or resolve conflict. An IMP may also include future land use and growth patterns, future development proposals, connected infrastructure systems, as well as other physical, social and economic development matters that the municipalities deem necessary for the area. A MDP must encompass many of those items that may be addressed in an IMP including: future land use and growth patterns, future development proposals and connected infrastructure systems. But it also must address municipal services, policies regarding land use near sour gas facilities, policies regarding municipal and school reserves, and policies regarding the protection of agricultural operations. A MDP may also include: municipal infrastructure financing, environmental matters, financial resources, economic development, development constraints of the municipality, as well as other physical, social and economic development matters that the municipality deems necessary for the area. The MGA requires that all municipalities with a population greater than 3500 inhabitants adopt a MDP (Government of Alberta 2000).

An Area Structure Plan (ASP) provides the basis for more detailed planning and design to the MDP, typically addressing general land-use allocation, residential density, transportation and environmental impact and general servicing (City of Calgary 2008).

In the City of Calgary, the Corporation Planning Application Group (CPAG) is a group of staff from various city departments including Development and Building Approvals, Transportation Planning and Parks Planning & Development that review planning applications and provide recommendation to the Calgary Planning Commission. The Calgary Planning Commission (CPC) is a committee that reviews land-use planning matters and makes recommendations to the city Council.

Figure 3 shows a summary of the Land-use Redesignation and concurrent Outline Plan process in the City of Calgary assuming a MDP and an ASP are in place (City of Calgary 2008).

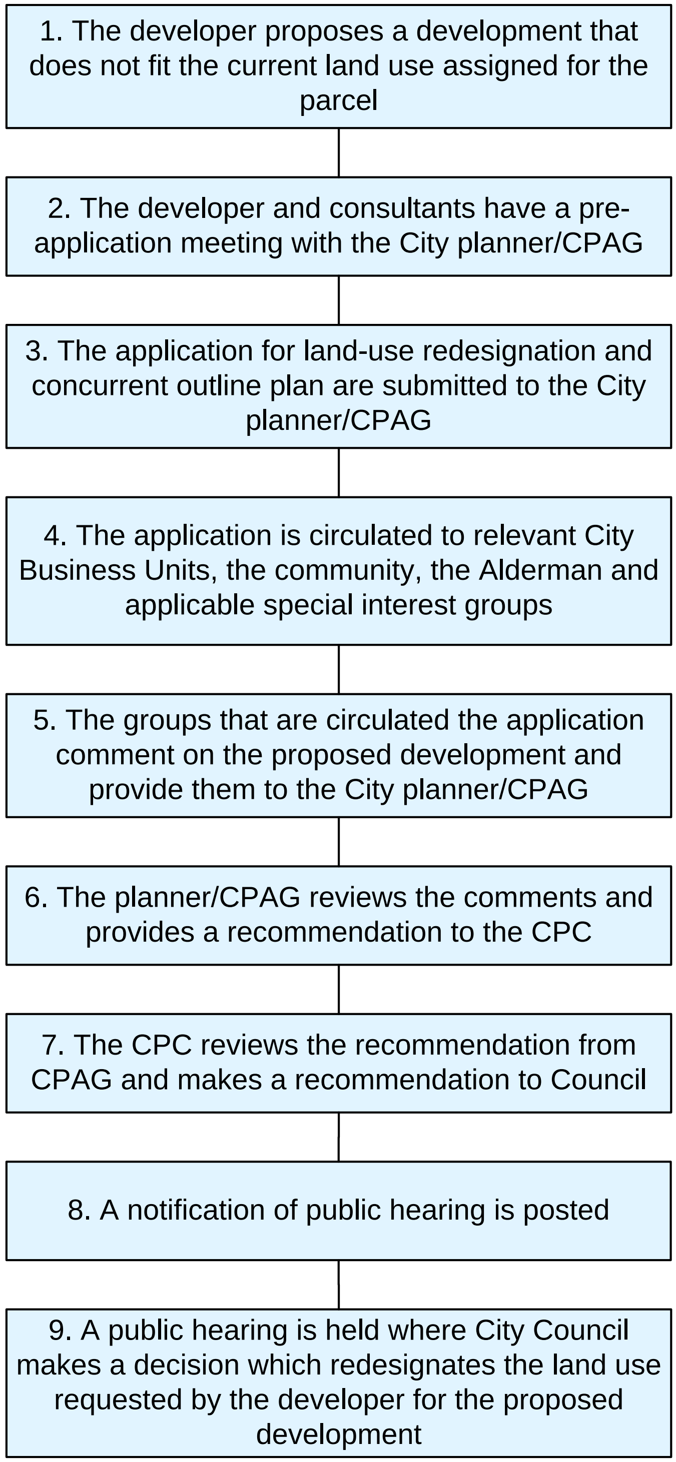

Figure 3: The land-use redesignation and outline plan application process

From hereon the *land development planning process* will refer to the Land-use Redesignation and Outline Plan application process as shown in Figure 3.

Land-use Redesignation (LU Redesignation) allows any person having legal ownership in a parcel of land to apply to have the land-use type assigned to that parcel of land changed to another land-use type more suitable for their proposed development. A developer will typically combine LU Redesignation with an Outline Plan (OP) application. An OP must follow the guidance given by the approved ASP but it adds more form and detail into the size and location of roads, parks, and land use; however it does not show individual lots. Depending on the comfort level, degree of risk, and time constraints put on the developer, if subdivision of the parcel of land is required, this may also be done in conjunction with an Outline Plan. The process for the combination of LU Redesignation and OP involves:

1. Have a pre-application meeting with the city/town planning authority to discuss the proposed redesignation;
2. Voluntarily present the plan to the neighbours and local community association;
3. Submit the application for land-use redesignation and outline plan to the planning authority including:
    a) An outline plan report discussing the proposed land-use, the proposed development in context with neighbouring developments and how it fits with the approved ASP.

b) An engineering servicing report which discusses the location and size of the proposed infrastructure and their tie-in locations to existing infrastructure, based on information provided by the city/town authorities.

c) A preliminary storm water management report containing preliminary design and emergency overland drainage flows, based on information provided by the city/town authorities.

d) A geotechnical report based on soil samples that discusses soil types, construction requirements and slope analysis.

e) An outline plan showing existing and proposed infrastructure including: location and size of roads, curbs, sidewalks, paths, water, sanitary sewer and storm sewer pipes and their tie-in locations to existing infrastructure, location of sanitary and storm manholes, location of storm catch basins and drainage swales, location of fire hydrants, existing topography, proposed site grading, parks and public transportation facilities.

4. The application is circulated to the various City departments, the community association, the Alderman, and any applicable special interest groups and a notice is posted on the site;

5. 6. & 7. The various planning authorities review the application and the comments and make a recommendation to council;

8. Notices are sent to adjacent owners, a sign is posted on the site, and an advertisement is placed in the local newspapers regarding a public hearing on the application;
9. The proposed land-use redesignation and outline plan application are presented in a public hearing and the City Council makes its decision.

The process is similar in the Town of Strathmore. However, the administration is smaller and is not divided into as many individual departments resulting in fewer decision makers making more decisions.

As one can see, the development approval process described above involves many stakeholders including: the landowners, the developers and their engineering and planning consultants, the city/town authorities and their various departments, the neighbours, the community associations, other citizens, the city/town political figures, the utility providers, and other special interest groups. One can also imagine each stakeholder or group of stakeholders having different visions, opinions and interest in the proposed development and therefore having different goals that they try to achieve. The authorities must also see the broader picture and overall goals of the city/town itself, and attempt to see how the proposed land development fits into the future plans that have been developed for the community.

Throughout the process, communication occurs between different stakeholders on many occasions, both internally within an organization and externally with other organizations. Communication also occurs at many formal and informal levels, including: pre-application meetings with city/town authorities, meetings with neighbours and community associations, meetings with private planning and engineering firms, open houses, application reviews by authorities and the public, decisions by city/town authorities, public hearings, and possible appeals. Prior to these communication sessions, stakeholders are trying to devise ways to fit their goals into the proposed development. During the sessions, goals and issues are discussed and negotiations take place to balance goals and resolve issues and hopefully make decisions. As stakeholders make decisions, they might weigh social need, environmental impact, economic advantages or disadvantages and political support or opposition of a proposed land development.

Increasingly, computer simulation models are being used to support decision making in complex environmental management situations (Marceau 2008). The *land development planning process* is the type of complex system where a computer simulation model can provide this support.

1.3 What is simulation modelling?

A model is a computer program that attempts to emulate a real-world system. However real world systems are too complex to be modeled in their entirety; they have too many subjects making too many decisions based on too many influences, generating too many small events, which combined together in some intricate fashion define the overall pattern of the system. The designer of a model must abstract a complex system to the point where the minimum number of components, generates a minimal number of events that are most influential in defining the overall pattern of the system.

Models typically have time, space, and scale constraints, meaning they are limited to function within a certain period of time with a certain periodicity, and they function on entities of a certain size within a particular geographic region. These constraints are set upon the model by the developer and simulating outside of these domains might surpass thresholds beyond which the results are no longer valid. Models can be spatially enabled or non-spatially enabled, dynamic or static, discrete or continuous, disaggregate or aggregate, and deterministic or stochastic (Perez & Batten 2006).

Agent-based models, also called multi-agent systems, are an abstraction of a process into subjects called agents. Agents typically have the following properties: they are autonomous, they control their own decisions and actions, and are not driven by others; they are social, they use a 'language' to negotiate and cooperate with one another; they are reactive, they are able to perceive changes in the environment and react to them; they are also proactive, they have goals and are able to take initiative to achieve them (Wooldridge 2000). Agent-based models are typically discrete, disaggregate, dynamic and spatially explicit, meaning that they simulate the processes that occur between individual agents over time and they interact within and act upon a simulated geographic region.

Agent-based models have been developed for a number of purposes including: wildlife management (Bousquet et al. 2001; Anwar et al. 2007; Beardsley et al. 2009; Bowman & Thompson 2009), natural resource management (Janssen et al. 2000; Feuillette et al. 2003), urban simulation (Batty 2001; Waddell 2002), spatial planning (Ligtenberg et al. 2001), and land-use and land-cover change (Lim et al. 2002; Parker et al. 2002; Monticino et al. 2007; Moreno et al. 2007; White et al. 2009).

1.4 Previous research involving agent-based models

In recent years, several agent-based models have been developed to simulate land-use/land-cover change. Parker et al. (2002) characterize an agent-based model that simulates land-use/land-cover change as being comprised of two components: an agent-based model, and a cellular model. The agent-based model represents humans making decision and interacting over their environment as agents that follow rules in their decision making and interact and act within a simulated environment. The cellular model is a cell-based map that simulates the environment that agents view and act upon. These two characteristics are fundamental to the model developed in the research underlying this thesis.

Lim et al. (2002) developed the LUCITA (land-use change in the Amazon) model to look at how decisions made within individual households at the local level interacting with their environment can effect land-use change at a higher level. The LUCITA model attempts to understand land-use changes in the Altamira region as a result of agricultural practices at the individual household-level including family characteristics (age, gender, available labour pool, and available capital), environment characteristics (soil type, topography and water availability), and economic factors (distance to markets, credit policies, and commodity prices). The LUCITA model is composed of ecological and human system sub-models that interact through a raster-based environment. The ecological sub-model simulates the impact of deforestation on the soil and the impact of soil on crop success and natural reforestation. The human sub-model simulates agents that represent a family with the following properties: family composition, available family, male labour pool, and available capital. Agents have an internal representation of their environment; each agent is aware of the boundaries, its capacity to impact the environment, and land-cover types that makeup its environment. The model attempts to test the conceptual model of McCracken et al. (1999) which states that as colonists in the frontier get older, their decision-making strategies shift from highly intensive deforestation strategies (involving minimal labour and capital, with low economic return) to less intensive deforestation strategies (involving higher labour and capital, with high economic return). Throughout the simulation, agents perform repeated actions, such as:

land deforestation, burning, growing crops and harvesting crops. At the beginning of a simulation, the user sets preferences that define the agents' ability to identify cells on which to act. Land-use strategies are stored as rules; each agent has eight rules that reflect its strategies for agriculture production which strengthen or weaken depending on if a rule produces a successful or unsuccessful crop yield. The authors did discover several weaknesses in the model with the rule modifier and an assumption on household capital growth giving biased land-use changes. However, it was not their intention to replicate the real-world system but rather to study the change of land use from the bottom up, looking at the decisions made by many individuals and how the landscape changes as a result (Lim et al. 2002). Their research provided direction in the development of the conceptual and decision flow models for this research.

Moreno et al. (2007) developed a similar model to that of Lim et al. (2002). The BIOCAPARO model is a multi-agent model that simulates the relationship between human and natural ecosystems using land-use change as a result of decisions made by settlers regarding agricultural practices in the tropical forests of the Caparo Forest Reserve in western Venezuela as a case study. The model simulates the decisions and actions of settlers and loggers based on existing government policies and the land-use change that occurs as a result. The settler agents practice subsistence agriculture for five years, until typically soils become exhausted, and move on. The logging agents extracts resources from the forest, replants the forest and monitors the plantation for two years and can ignore settlers or inform the government of their presence. The government agent monitors the logging operations and responds to settlement monitoring from the loggers. The model was run on the three government scenarios: hands-off, pro-forestry and agro-forestry. The model produced results similar to what is generally known about the management and evolution of tropical forest harvesting. However it was discovered that recuperation of the tropical forest to its original vegetation density and diversity takes longer than previously thought. The authors believe that through behaviour change in the agents, sustainability could be achieved in the Caparo Forest Reserve. They also mention that the model can be improved by including population growth, landlord agents, detailed government agent evaluation of concessionaire and a more realistic ecological CA model. This research provided guidance for this project in the abstraction of the environment into a raster-based map as well as in the development of the rules by which the environment changes.

Monticino et al. (2007) developed a multi-agent model to simulate the effect that the values held and the decisions made by municipal government, land developer, land owner and homeowner stakeholders have on land-use change in a region in north central Texas, USA, that has been experiencing rapid urban growth. The authors emphasize the knowledge that urban developments are impacting many forest ecosystems. The impact of governmental regulations and developer decisions on the environment is an important area of study. The decision-making process of the agents in the model is based on their values that are quantified statistically in a decision analysis function, which uses a multi-attribute utility function to evaluate each action and selects the action with the highest weight. The model generates land-use change patterns similar to those actually observed in this area of Texas and reveals that land value and neighbouring developments are the key drivers of land-use change. The authors recognize the value in the model they developed and for understanding the impact that public policy, stakeholder goals and interactions have on land-use change. This research provided direction in the quantifying of governmental regulations, agent properties and decision making in this research.

There are many existing programming environments for simulating agent-based systems including Swarm (Minar et al. 1996; Swarm 2010), Repast (Crooks 2006; Repast 2010), Mason (Mason 2010), and NetLogo (NetLogo 2010). However, as discussed in the following section, it was determined that since this research models the processes in a specific case study a new model had to be developed to meet these particular needs.

1.5 Objective of the study

The objective of this research is to develop and build an agent-based computer model that simulates the land development planning process in a case study context. The case study is a proposed residential subdivision in the Town of Strathmore called Strathbury. The land development planning process includes the Land-use Redesignation and Outline Plan process as shown in Figure 3. The model will be used to investigate the impact of changes to governmental regulations, planning policies, design standards and stakeholder goals on land-use resources. For the purpose of this research, land-use resources are parcels of land having a potential for development, that currently do not have the land-use designation to allow for development but that could be redesignated. The research is quite similar to that of Monticino et al. (2007) only over a much smaller area and at a finer scale. It is hoped that this model can be further used by provincial, municipal, urban and town planners to simulate the effect of different scenarios of regulations, policies, standards, and goals on land-use resources, allowing them to envisage the possible future impact prior to their implementation and helping them make better decisions.

1.6 Organization of the thesis

The balance of this thesis is organized in the following manner. Chapter 2 describes the methodology that was used in developing the model. Chapter 3 presents the results of the simulations that were preformed. Chapter 4 draws conclusions and presents recommendations for future work.

Chapter Two: Methodology

This chapter is separated into nine sections. The first section introduces the steps involved in developing a computer simulation model. The following eight sections detail how each of the steps were accomplished for this research including: identifying the study area, developing the conceptual model, identifying the parameters, variables and assumptions, defining the environment and its boundaries, building the computer model, calibrating the model, developing scenarios, and validating the model results.

2.1 Model development

The following eight steps in creating the agent-based computer simulation model, recommended by Kimmins et al. (2004) and Wainwright et al. (2004), have been applied in this research:

1. Identification of the study area;
2. Abstraction of the real-world system: a conceptual model is developed to define the key components, their properties, and actions that are fundamental in defining the real-world system being modelled. A UML diagram is used to illustrate the abstraction;
3. Collecting the information used in implementing the model: this critical step explains how the goals, the decision process, and the factors influencing their decisions were acquired from each stakeholder, as well as identifying the environment in which they impact;

4. Implementation of the model: this step illustrates the properties and functions of each agent type, and the agent-agent interactions. This step also explains how the environment and the agents-environment interactions were implemented in the model. The spatial and temporal boundaries of the model are also presented;
5. The computer model: this step describes the software used in developing the model, the computer model interface and the computational logic. A process/decision flow diagram is used to illustrate the procedure;
6. Calibration and verification of the model: this step explains how the initial conditions of the stakeholders in the Strathbury development were used to verify if the model was running properly and produced realistic results;
7. Simulation scenarios: this step defines the different scenarios and initial conditions that were tested in the model; and
8. Validation of the model results: this step explains how the credibility of the model was assessed by expert opinions.

2.2 The study area

The study area for this project is a proposed residential land development project called Strathbury corresponding to a 80 hectare undeveloped piece of property located about 0.5 km northwest of the downtown core of the Town of Strathmore; it is within the adopted Strathmore Lakes Estates Area Structure Plan (ASP). The simulation scenarios were tested over an area of approximately 3000 hectares that includes the Town of Strathmore and approximately 1.6 km of the surrounding Wheatland County, shown as a dashed line, outside of the newly annexed Town boundary, shown as a continuous line, as illustrated in Figure 4.

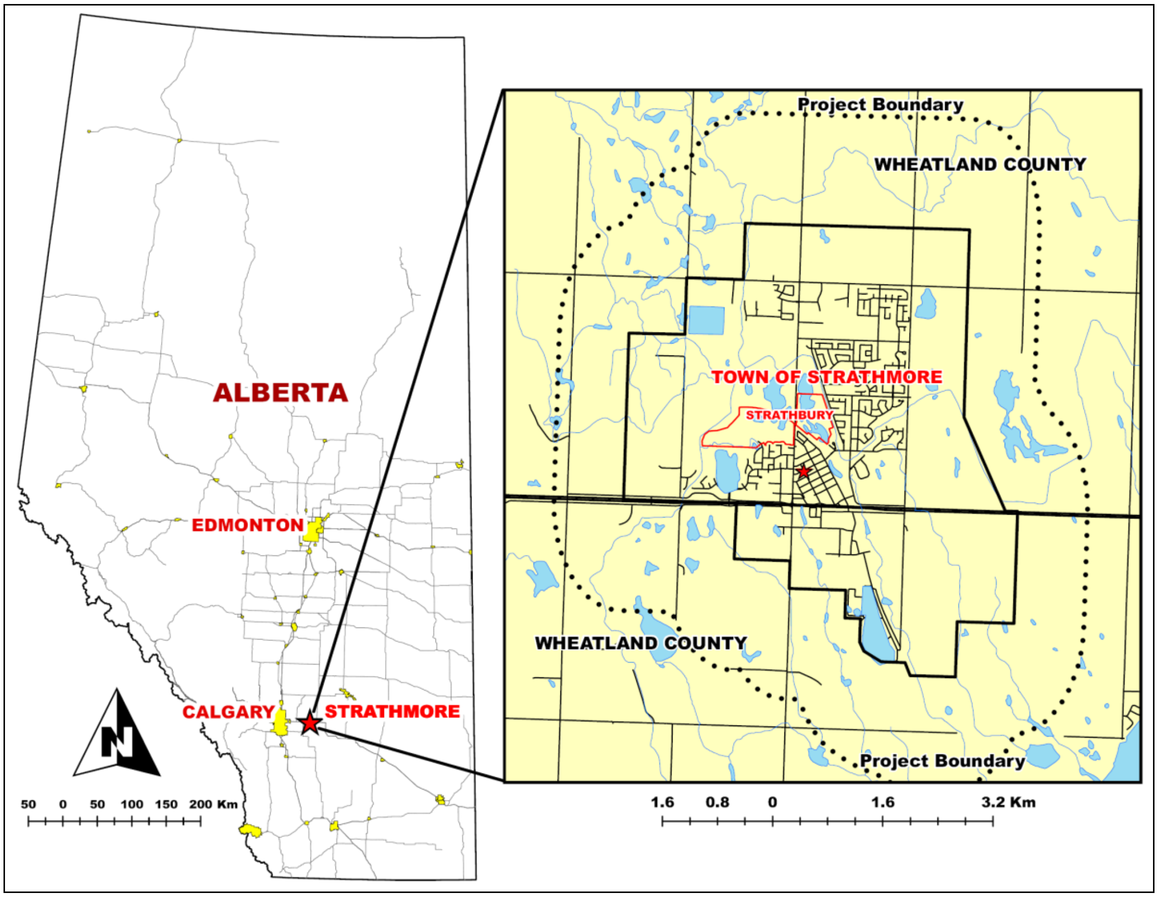

Figure 4: Location of the study area

2.3 Abstraction of the real-world process

As mentioned previously, two components, an agent-based model and a cellular model were used to create the whole model in this study. This required the identification of the key agent-based model components and the key cellular model components that simulate the real-world *land development planning process*. The model was started as a simple abstraction but complexity was added when needed during its development.

2.3.1 Agent-based component

The key stakeholders that were abstracted from the real-world *land development planning process* were the Developer, the Planner and the Citizens.

The Developer combines those stakeholders that have financial interest in the development of the Strathbury project: the land developer who will profit from the conversion of the land into developable lots, and the engineering and planning firm who was providing consulting services to the land developer who will profit during the planning and preliminary engineering stages.

The Planner combines those stakeholders that ensure the proposed land development follows governmental regulations with those in political positions that make decisions on the approval of proposed developments in the Town of Strathmore. They are the municipal planning department, the infrastructure department, the parks and recreation department, the emergency services department, and the Strathmore Town Council. The Town of Strathmore is a small municipality having only one Town Planner that advises the Town Council on a proposed development. The political arena, the Town Council, is not included in this model; therefore the assumption is made that the advice of the Town Planner on a proposed development is the decision of the Town Council.

The Citizen includes those stakeholders that neighbour the proposed development, community associations, and other citizens in the Town of Strathmore. The citizens of the Town had particular environmental concerns regarding the Strathbury development and are therefore considered a key stakeholder.

Although electrical, gas, and communications utility providers do have financial interest in a proposed development, typically they are not involved in the decision making and are therefore not included in the model. Typically, if some utility infrastructure exists within the proposed development, such as high pressure gas, electrical transmission or communication towers, the proposed development may need to be planned around the existing facilities. If they can be relocated, the utility company may financially make the development more or less feasible by either absorbing the cost of utility relocation or passing the cost of relocation onto the developer.

2.3.2 Cellular component

The key environmental state that was abstracted from the real-world *land development planning process* was the land-use designation on each land parcel. The environment was abstracted into raster-based cells of a uniform size with land-use values as attributes.

2.3.3 The conceptual model

The conceptual model, expressed as a UML diagram (Figure 5), shows the two model components, the agent-based model and the raster-based land-use change model that were built to simulate the *land development planning process*. The agent-based model simulates the planning process including the goals, interactions, and decision making of stakeholders, taking into account economic factors, social factors, and regulations. The raster-based land-use change model simulates the environment that is deliberated, applies the land-use change from an approved development and simulates into the future.

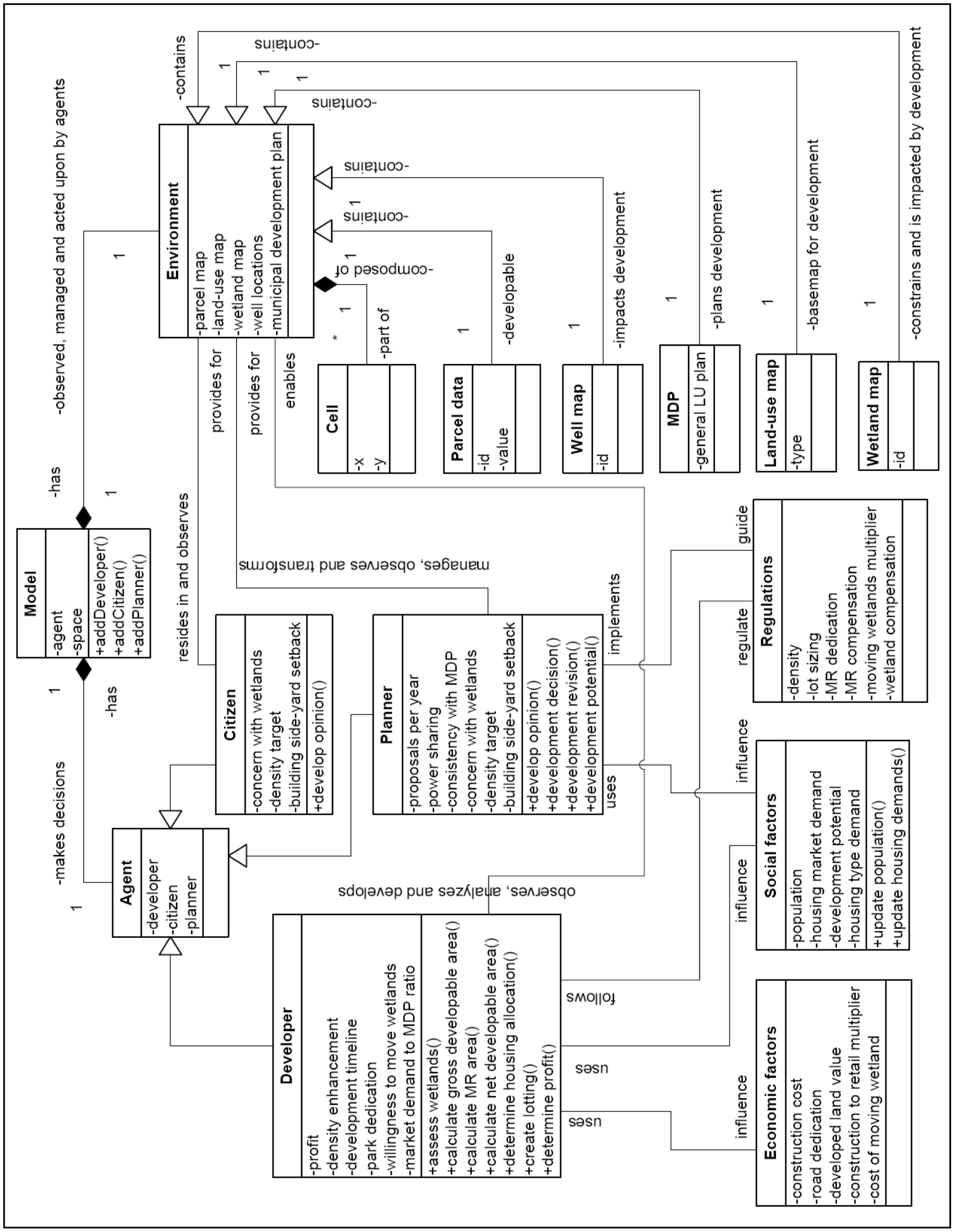

Figure 5: The conceptual model

2.4 Information used in implementing the model

Five different types of information that are used in the *land development planning process* were gathered and were implemented in the model: 1) agent information, 2) spatial datasets, 3) social factors, 4) economic factors, and 5) government regulations.

2.4.1 Agent information: goals, decisions and factors influencing decisions

As mentioned in Section 1.2, the stakeholders have a different vision for a proposed development, they have different goals that they are trying to achieve, and their decision is influenced by different factors in the *land development planning process*. A key component of the model is gathering the goals and influencing factors from each stakeholder. The first step in developing this model was to determine for each of these stakeholders, namely the Developer, the Planner and the Citizen, the specific goals they are attempting to fulfill, how they make decisions, the factors that influence their decisions, and how they communicate with each other.

For the Developer and the Planner stakeholders this information was gathered in three stages: through a questionnaire, a formal interview, and an unstructured interview. Individuals that were directly involved in the Strathbury *land development planning process* included: the Planner for the Town of Strathmore, and the Strathbury land developer from WestCreek Developments. A Professional Civil Engineer from Eclipse Geomatics & Engineering, who was contracted by the developer to do the engineering for the proposed development and who is considered an expert in the field of land development, was also contacted to provide information on the status of the Strathbury application, public hearing and council decision process, as well as insight on the *land development planning process* in the Town of Strathmore, the governmental regulations affecting land development, and the land-use change allocation.

Since this research involved the use of human subjects, it required review and approval by the University Research Ethics Board. This application to the University of Calgary Conjoint Faculties Research Ethics Board included project details, recruitment of subjects, estimation of risks, maintenance of privacy, informed consent and a sample of interview questions.

A questionnaire was prepared (Appendix 1) based on preliminary discussions with the Town Planner and the Professional Engineer. It was provided to each representative stakeholder to answer. The information collected from the questionnaire was used to guide the structured interview. During the structured interview process, it was discovered that although the questions provided a general understanding of the factors influencing the decision process of the stakeholders, the depth was insufficient. An unstructured interview ensued allowing the representatives to talk freely about the planning process, their goals, how the decision process occurs, the information they use to make their decisions and how the *land development planning process* was going with the Strathbury project. The questionnaire and the two interviews complemented each other providing structure from which to formulate the *land development planning process* and yet enough candidness to gather personal goals.

For the Citizen stakeholder it was concluded that questioning only one citizen would be biased and questioning many citizens was unwarranted. During the unstructured interview, the Planner provided information on feedback he received through written and verbal communication with concerned citizens. In the public consultation for the Outline Plan and Land-use Redesignation associated to the Strathbury development, some motivated citizens provided written comments on the proposed development. These comments became part of the public documentation for the development and are summarized and addressed by the developer. Although this information may not represent the opinion of all citizens, it was the best available to represent the perspective of the Citizen stakeholder in the model.

The notes taken during the interviews with the Town Planner and the Strathbury developer, and the letters collected as feedback from the citizens were compiled into stakeholder goals, decision making process, factors influencing decisions, and interaction. The City of Calgary (2002) document entitled “A Community Guide to the Planning Process”, outlines the general Land-use Redesignation and Outline Plan process and like most municipalities in southern Alberta, it is followed by the Town of

Strathmore. This document formed the foundation of the first step in the model design, which was determining who makes decisions, when the decisions are made, by which stakeholders, and how interactions occurs between these stakeholders. The second step was identifying the factors that influence the stakeholders' decisions. The third step was determining the goals that each stakeholder is trying to achieve for each factor. This is discussed in further detail in the following section.

2.4.1.1 Developer stakeholder: goals, decision and influence

During the interview, the developer explained the general objectives that his company attempts to meet with all proposed land developments, including: profit, density, construction cost and timeline, and lot retail value. The developer discussed the general infrastructure issues that the Town of Strathmore needs to address prior to approving any development projects including: sweet gas well buffers, water sourcing and water treatment, sanitary sewer disposal, and storm water management. He also discussed specific details that pertain to the Strathbury development of which wetlands were the most controversial (Developer 2007).

The land developer wishes to maximize the number of market demanded lots by minimizing the lot size and increasing the density, to minimize costs - hence maximize profit, to provide building lots quickly, to provide the required Municipal Reserve (park space) rather than monetary compensation to the Town, to move wetlands when they interfere with the proposed design, and to follow the market demand for housing rather than the Municipal Development Plan. From this information, six properties were abstracted to become the Developer stakeholder goals: 1) profit, 2) increase residential density, 3) development timeline, 4) park dedication, 5) willingness to move wetlands, and 6) market demand to MDP ratio.

Many regulatory factors dictate the decisions of the land developer when planning a development including: the municipal development plan, the current and adjacent land use, the municipal land-use bylaw, the environmental regulations, and the law. Also, many economic factors influence the decisions of the land developer including: the housing market demand, the market value of developable lots, the construction cost, the cost of developable land, the distance to existing infrastructure, and the presence of wetlands within the land parcel. When making the decisions on a proposed development, the developer looks at different development schemes, applies the regulations, assesses all the influencing factors, and then “calculates” the most suitable and profitable scheme. If the developer performs his/her “due-diligence”, the proposed development plan on a parcel of land should be accepted (Developer 2007).

2.4.1.2 Citizen stakeholder: goals, decision and influence

Citizens are the source of values that define the community. They identify problems and provide feedback on solutions that are implemented. Typically the more involved citizens are in the community, the more influence they have on decisions affecting their community.

The comments provided by the citizens proved to be very useful in developing their general concerns regarding the Town's growth, the typical 'not in my back yard' (NIMBY) apprehension, the need for a park system, and the preservation of wetlands. The following quotations come from six different letters received by the Planner regarding the Strathbury project and are reflective of the comments given by the Planner during the interviews (Citizens 2006):

- "strongly oppose the proposed amendments for the redesignation of the land directly behind our home"
- the town "promotes green areas and Urban Reserves yet is proposing to build homes and condos on one of the most beautiful green areas remaining" in the town
- "the land has numerous ponds and we're very concerned about the water level specifically where the water will flow if homes are built in the area"
- "preserve (the Strathbury land) and further enhance it so that future generations of our residents and our wildlife will have the space to access"
- "we are desperately in need of areas to walk with our families"
- "we (want to) look well into the future and plan not only residential, business and shopping spaces, but areas (that) will enhance (the) quality of life"

- “(the Strathbury land) is really an extension of the wetland across the road, and has several smaller wetland areas within it. Please preserve it with a plan for enhancement in the future”.

The compiled information revealed these general desires of the citizens: they like the small town feel and they want to maintain it, they do not want the urban sprawl of Calgary, they like the network of walking trails within the town, and they feel the wetlands in their community are a great asset and want to maintain them as part of their park system. The Town planner verbally communicated a concern with the fire hazard associated with houses being excessively close. From this information, four properties were extracted to represent the Citizen goals in the model: 1) concern with wetland disturbance, 2) maintain Municipal Reserve (park space), 3) maintain density per the MDP, and 4) increase building side-yard setback.

In general the citizens’ are greatly concerned by the impact on wetlands and the continuity of their park network. They evaluate the development proposal created by the developer mostly in terms of the impact on wetlands and the integration of park space and share their positive or negative opinion with the town planner.

2.4.1.3 Planner stakeholder: goals, decision and influence

During the interview, the Town planner described the Town's current zoning bylaws, the infrastructure issues, the trail network system, the municipal development plan, the density objectives, the future growth plans, and the wetland policy, which was recently updated following a public survey of the town's residents. He/she also talked about his/her role as a sounding board to residents' concerns and as an advisor to the Town Council. Details pertaining to the Strathbury development project itself were also discussed, including a goal of slightly increasing the density on account of its vicinity to the town centre, and the issue of wetlands (Planner 2007).

During the interview, some frustration was expressed in having inherited an aged Municipal Development Plan and having to work with existing Planning Policies that really didn't match the sustainability, density and growth goals that were now desired. For over a year, the town planner had worked with the Town council on a new Municipal Development Plan (MDP) and almost had it adopted by the Council. At the time of the interview, the Town had just had a Municipal election that completely changed the Council members. As a consequence, the Planner would have to go through the entire process again before adopting the new MDP.

The town planner must interpret planning regulations for other municipal decision makers and be able to educate citizens about the benefit of community planning. He is the moderator between the land developer and the citizens over the wetland issues while meeting the needs of the growing community. He is also the citizen educator providing an open door for citizens wishing to discuss community planning and future plans of the Town. Opinions of citizens showing an interest and a genuine concern for the direction of the community planning within the Town of Strathmore are given more credence by the Planner. The information compiled from the interview revealed specific desires that the planner wishes to achieve for the Town: to implement a new community growth strategy (MDP) with a transit-oriented design, allowing for an increase in density in redevelopment areas near the town centre, to provide direction for the new developments within the recently annexed Town boundaries, and to solve storm and sewer infrastructure problems. From this information, seven properties were extracted to represent the planner goals in the model: 1) development approvals per year, 2) weight of citizens' opinion, 3) consistency with the town's municipal development plan, 4) concern with wetland disturbance, and the increase/maintain/decrease of 5) Municipal Reserve (park space), 6) density, and 7) building side-yard setback.

There are many regulatory factors that dictate the decisions of the planner when planning a development including: the municipal development plan, the current and adjacent land use, the municipal land-use bylaw, the environmental regulations, and the law. As the planning division in a city/town is the authority on the municipal land-use bylaws and the Municipal Development Plan, the planner has the ability to interpret them differently.

This flexibility has been captured in the “consistency with the town’s municipal development plan” property of the planner. There are also many social factors that influence the decisions of the land developer including: the citizen involvement, the housing demand, the urban development potential, and the population growth. A key decision that must be made by the planner is related to the sharing of decision-making power with the citizens: the greater the involvement of the citizens, the more decision-making power they are given. The planner must evaluate the development proposal created by the developer in relation to the town’s goals and the existing regulations. Then, a decision is made to accommodate the opinion of the citizens, the housing demand and the town’s municipal development plan, and the right of land owner, represented by the land developer, to develop his/her property.

The planner is also responsible for updating the MDP every five to ten years, a process that involves public hearings, public consultation, and growth prediction. Since the new MDP had not yet been approved by Town council, it was not public documentation and therefore could not be supplied; however the planner provided some information on its general direction (Planner 2007).

2.4.2 Spatial datasets

A GIS (Geographic information system) database was developed using the ArcGIS software from Environmental Systems Research Institute (ESRI) to integrate the relevant information about the study area. The following is a list of the spatial datasets used in the model:

- *Cadastral parcel*: AltaLIS (2007) cadastral parcel data were obtained from the University of Calgary Maps, Academic Data, Geographic Information Centre (MADGIC) in vector format. The assumption was made that large undeveloped or Greenfield land parcels, closer to existing infrastructure, and closer to the center of the Town of Strathmore will be developed first. Therefore, urban reserve (UR) and agricultural (AG) parcels were weighted according to their size, distance to existing roads, and distance to the downtown core of Strathmore. Parcels were sorted by their weight, highest to lowest, and given a unique parcel identifier (Parcel No. 1, 2, 3…); the Strathbury project was Parcel No. 2 in the sequencing.
- *Land-use map*: the AltaLIS (2007) vector cadastral parcel data were attributed land-use values from the Town of Strathmore (2007): 1, 2, 3, 4 = various types of commercial, 5 = public service, 6, 7 = various types of industrial, 8, 9, 10, 11, 12, 13 = various types of residential, 14 = municipal reserve, 15 = environmental reserve, 16 = open space, 90 = agriculture, 91 = urban reserve, 92 = Western Irrigation District (WID) canal, 99 = road.
- *Municipal Development Plan (MDP)*: the quantifying of the MDP required the rework of the land-use map in the existing MDP (Town of Strathmore 1998) based on the information provided by the planner during the interview. In general the MDP requires 45% residential one (R1), 25% residential two (R2) and 30%

residential two-X (R2X). Each residential parcel was given land-use percentages based on the information provided and stored as: [Parcel No., 45, 25, 30]. The Strathmore Lakes Estates Area Structure Plan further regulates the percentages of the Strathbury lands to 30% R1, 45% R2 and 25% R2X; therefore its values are stored as: [2, 30, 45, 25].

- *Wetland map*: The Strathmore Wetland Inventory map from the Town of Strathmore (2007) was digitized into vector format.
- *Gas well locations*: Alberta Energy Resources Conservation Board (ERCB) (2007) well site data were obtained from MADGIC in vector format.

2.4.3 Social factors influencing stakeholders' decision

Population growth and housing demand are influential in the decision making of the Planner, Developer and Citizen, making it necessary to balance the appropriate type and quantity of housing. The following is a list of the social factors impacting decisions abstracted for the model and how they were quantified as parameters in the model:

- *Population growth*: the population of the Town of Strathmore in 2007 was 10728 persons (Planner 2007); but the estimated population growth was calculated on a yearly basis from a population projection report (CH2M HILL 2007).
- *Housing market demand*: an initial approximate value for the Town is 50 units (130 persons) in 2007 (Planner 2007). The future demand is calculated in the model on a yearly basis as the population growth, less the number of new homes

created that year, multiplied by the average household size (2.6 persons/household) (Statistics Canada 2007).

- *Development potential*: it is a value estimated by the Planner that is based on the residential construction in approved residential land developments in the Town. Based on the approved developments, an estimated 125 units (325 persons) could be built in 2007/2008 (Planner 2007).
- *Housing type market demand*: initial values (50% R1 (residential one), 15% R2 (residential two) with a 25’ wide lot, 10% R2 with a 30’ wide lot, 15% R2Xatt (residential two-X attached), and 10% R2Xdup (residential two-X duplex) for each housing type for the Strathbury development were provided by the Developer during the interview (Developer 2007). Since the market study only covered the Strathbury development, these numbers are assumed constant.

2.4.4 Economic factors influencing stakeholders’ decision

The land cost, construction costs, and market value for developable lots are influential in the decisions made by the Developer. The following is a list of the abstracted economic factors and how they were quantified as parameters in the model:

- *Land value*: assessed land values ($/hectare) were obtained for each developable cadastral parcel from the Assessment Offices of Wheatland County (2007) and the Town of Strathmore (2008). Knowing that the market land value for the Strathbury development land is approximately 2.5 times the assessed value, an assumption was made that all market values were 2.5 times the assessed land value.

- *Construction cost per metre of frontage*: from experience, the developer has determined an approximate cost per linear metre of lot frontage that includes all the construction costs of $3000/foot of lot frontage ($10000/m of lot frontage) (Developer 2007).
- *Percentage of road dedication*: from experience, the developer has determined an average percentage of the developable area that is dedicated to roads of 29%, of which 34% are 22 m wide collector streets and 66% are 15 m wide local streets (Developer 2007).
- *Developed land value*: from experience, the developer knows the approximate retail value for the different housing types (residential-1 lot (R1): ~$450000, residential-2 25’ wide lot (R2-25): ~$250000, residential-2 30’ wide lot (R2-30): ~$300000, residential-2X duplex lot (R2Xdup): ~$225000, residential-2X attached lot (R2Xatt): ~$200000) (Developer 2007).
- *Construction to retail value multiplier*: from experience, the developer has devised a multiplier to use when determining the development feasibility and profit. The minimum retail value should be three times the construction cost. If the construction costs are lower or the retail value is higher then a profit is made. Conversely, if the construction costs are higher or the retail value is lower then a loss is declared (Developer 2007).

- *Cost of moving wetlands*: According to the Alberta Government (2000) the cost of constructing wetlands varies between $12,000 and $60,000 per hectare. Included in these costs are the land, design, earth moving, planting, monitoring and maintenance.

2.4.5 Governmental regulations

Municipal governmental regulations, implemented by the Planner, must be followed by the Developer when proposing a development. The following is a list of the abstracted governmental regulations and how they were quantified as parameters in the model:

- Land-use bylaws:
  - *Density*: the average density as outlined in the Land-use Bylaw and MDP is 15 units/hectare (6 units/acre) (Town of Strathmore 1998).
  - Lot sizing: the minimum lot width and lot area values were obtained from the Strathmore Land-use Bylaw (Town of Strathmore 1989).
    - *Minimum lot area*: R1=464 m^2, R2-25=255 m^2, R2-30=302 m^2, R2Xdup = 232 m^2, R2Xatt = 185 m^2
    - *Minimum lot width*: R1=15 m, R2-25=7.6 m, R2-30=9 m, R2Xdup = 7.5 m, R2Xatt = 6 m (Town of Strathmore 1989; Town of Strathmore 1998).
  - *Percent MR dedication* or *MR compensation*: The Alberta Municipal Government Act requires that proposed subdivisions provide part of the

land as municipal reserve (MR) not to exceed 10% or monetary compensation (Government of Alberta 2000).

- Environmental regulations:
    - *Moving wetlands multiplier*: in some situations, developers may consolidate existing wetlands within a proposed development. Relocating wetlands can be damaging and they are typically less productive. Wetland of 100 to 300% of the original wetland size may be required.
    - *Wetland compensation*: in situations where wetlands are destroyed, a monetary compensation of ~$18,000/hectare must be paid to an environmental protection organization.

2.5 Implementation

This section presents how the five types of information described in the previous section were implemented within the model.

2.5.1 Agent implementation: properties and decision functions

The three different stakeholder types, the developer, the planner and the citizen, were modeled as three different types of agents: the Developer, the Planner and the Citizen. The goals and the factors influencing the decision of each stakeholder type were abstracted to become the properties of the agents, and the decision making was abstracted into decision functions with property variables. The properties and results of decisions from each agent type described in the following three sections are quantified as numerical values. These values are stored as arrays of numbers, or tuples.

In the implementation, each agent type was given an *opinion* property that range from -1 to 1 (negative opinion to positive opinion) and a *happiness* property that range from 0 to 10 (unhappy to happy). At different steps throughout the model, an agent evaluates the results of a decision and develops an *opinion*. A comparison is done between values contained in the decision tuple and values contained in each of the agent's properties tuple. If the result of a decision is contrary to an agent particular property, it will have a negative (-1) impact on his opinion regarding that property; if the result of a decision is similar to an agent property it will have a positive (+1) impact regarding that property. The average opinion is calculated and is weighted by ten less the happiness and is stored as the agent *opinion* property; therefore the *opinion* of an unhappy agent will be stronger. The *happiness* property of an agent fluctuates according to how his *opinion* is accepted. If his *opinion* is ignored in the following development decision, it will lower his *happiness* and if it is well received, it will increase his *happiness*. The following is an example of the calculation:

AGENT HAPPINESS:
Citizen: 8
Developer: 7
Planner: 8

AGENT PROPERTIES:
Citizen: maintain density of 6.0 and do not disturb wetlands
Developer: increase density and willing to move wetlands
Planner: increase density and do not disturb wetlands

PROPOSED DEVELOPMENT:
Developer: density of 6.5 and wetlands are disturbed

AGENT OPINIONS:
Citizen: -1 on density, -1 on wetlands, average = -1, weighted = -2
Developer: +1 on density, +1 on wetlands, average = +1, weighted = +3
Planner: +1 on density, -1 on wetlands, average = 0, weighted = 0

DEVELOPMENT DECISION:
Planner: approve

AGENT HAPPINESS:
Citizen: 6
Developer: 10
Planner: 8

Figure 6: Example of agent opinion and happiness calculation

Provision was also made for weighing each agent property allowing for different properties to be given more or less importance when making developing an *opinion*. This was implemented in a Multicriteria Decision Analysis fashion using an Analytic Hierarchy Process (AHP) method called the pairwise comparison (Malczewski 1999). Each pair of criteria, or properties, is evaluated separately; one property is given an intensity of importance value over another property. The values range from 1 to 9 (equal importance to extreme importance) and they are entered into a matrix form. The values in pairwise comparison matrix are then checked for consistency by normalizing the eigenvector by the eigenvalue of the reciprocal matrix. If the consistency ratio is less than a certain value, then the values are said to be consistent; if the consistency ratio is greater than the value, the importance values are not consistent and they must be re-evaluated. A weight for each property is also derived, the sum of which equals 1. The weights are then normalized with the smallest weight being equal to 1. The normalized weight is applied to each opinion (+1/0/-1) before the agent *opinion* is developed, as previously discussed.

The benefits of using this method over a straight rank weighting are twofold. First, the resultant weights are not only relative to one another, but they also have absolute values; second, the user only compares two goals at a time rather than subjectively weighting all goals at the same time (Malczewski 1999). The pairwise comparison method was used by Malczewski et al. (1997) in a multicriteria group decision-making model to analyze environmental conflict. In the model, stakeholders in planning or resource management positions evaluate the suitability of land for different socio-economic activities. The research of Malczewski et al. (1997) showed that the pairwise comparison method allowed the stakeholders to objectively derive weights for the various land uses, rather than subjectively assigning them.

An attempt was made to allow for behavioural change of the agents. The properties of the agents would vary based on their *happiness* and how successful their *opinion* was in a decision to which it contributed. Behavioural change proved to be too difficult to implement primarily due to a lack of information on actual behavioural change from the stakeholder representative, but also due to the multiple possibilities for change. Behavioural change could come as extreme approval (greed) or disapproval (protest), concede or persevere, or remain unchanged. As an example, a happy agent whose opinion was noticed might concede a little, might remain unchanged or might persevere further. An unhappy agent whose opinion was noticed might not change, might persevere a little or might become greedy. An unhappy agent whose opinion was ignored might protest or might concede.

2.5.1.1 Developer agent properties and decision functions

The properties of the Developer agent are stored in the *developer tuple* and were implemented as follows:

1. *Profit*: the goal on the return on the capital investment put into the land parcel: 5 to 20%.
2. *Density enhancement*: the goal to increase the allowable density: 0 to 2 units/acre.
3. Development timeline: the goal on the start and expected completion of construction. Also used to derive the *development potential* per year.
    a. *Start construction*: 1 to 5 years.

   b. *Finish construction*: 2 to 10 years.

4. *Park dedication*: The Developer's goal regarding the creation or monetary compensation of Municipal Reserve: create MR = 1, provide compensation = 2.
5. *Willingness to move wetlands*: The Developer's view on the displacement of wetlands to accommodate the proposed development: Move = 1, Don't move = 0.
   a. *Size of wetland moved*: The maximum size of a wetland the Developer is willing to displace: 1000 m^2 to 40000 m^2.
6. *Market demand to MDP ratio*: The Developer's stance when weighing the housing market demand versus the MDP: 0.1/1 to 4/1.

Typically an application for a development submitted to the town planner contains a report, several plans and other required independent studies. In the model, these documents have been abstracted as a sequence of numbers that translate the content of those documents submitted as a proposed development into a *development tuple*. The *development tuple* contains the results of the above Developer decision functions, which will be discussed next. The values contained in the *development tuple* include: the proposed cadastral unique parcel identifier, the proposed density, the timeline for the land development project, the percentage of each land-use type, the residential lot dimensions and number of lots of each residential type, and the wetlands proposed to be displaced.

The following is a description of how the eight decision functions of the Developer were implemented:

1. *Wetland assessment function*: The Developer calculates the size of wetlands impacting the development and determines if any wetlands are below their maximum *Size of wetland moved property (5.a.)*. If wetlands are to be moved, their total area is multiplied by the *Moving wetlands multiplier* and the area is added to the existing wetland area.
2. *Gross developable area function*: The Developer determines the amount of developable area, which is the gross area less the Environmental Reserve (ER) or wetlands from the *wetland map*.
3. *Municipal Reserve (MR) function*: The Developer determines the amount of land to be dedicated as MR (park) from the developable area based on the *Percent MR dedication* parameter.
4. *Net developable area function*: The Developer determines the area of developable area that will be residential and that will be road based on the *Percentage of road dedication* parameter.
5. *Housing allocation function*: The Developer uses the *Market demand to MDP ratio* property and weights the market demand for residential lot types: R1-detached, and R2(X)-semi-detached(attached), with the allocation in the *Municipal Development Plan (MDP)*.

6. *Lotting function*: The Developer determines the number of lots based on the *Minimum lot area* and *Minimum lot width* for each residential lot type, the *Density* regulation parameters, and its *Density enhancement* property; the lot depth is optimized to use all the developable area.
7. *Profit determination function*: The Developer determines the profit in the proposed development as the market value for sold lots, comparing the *Developed land value* to the construction cost, which is a function of the *land value*, *Construction cost per metre of frontage*, the amount of lot frontage, and the *Construction to retail value multiplier*.
8. *Opinion function*: The Developer compares, as discussed in 2.5.1, the appropriate values in the *development tuple* with the first five values in the *developer tuple*. Although the Developer follows its properties when initially proposing a development, due to the social and economic influences and governmental regulations the resulting proposed development may not meet its goals, impacting the *Developer opinion*. The Planner may also ask to revise particular aspects of the development, discussed in section 2.5.1.3, that do not meet the goals of the Developer.

2.5.1.2 Citizen agent properties and decision functions

The properties of the Citizen agent are stored in the *citizen tuple* and were implemented as follows:

1. *Concern with wetland disturbance*: The Citizen's view on the displacement of wetlands to accommodate the proposed development: Concerned = 1, Not concerned = 0.
    a. *Size of wetland moved*: The maximum size of a wetland the Citizen is willing to see moved: 1000 m^2 to 40000 m^2.
2. *Density target*: The Citizen's goal regarding the density in proposed developments: increase the density = +1, maintain the current level in the bylaws = 0, decrease the density = -1.
3. *Building side-yard setback*: The Citizen's goal regarding the distance between residential buildings as a fire protection measure: increase the current building setback = +1, maintain the current building setback = 0, decrease the current building setback = -1.

The following is a description of how the decision function of the Citizen was implemented:

Opinion function: The Citizen compares, as discussed in 2.5.1, the appropriate values in the *development tuple* with the values in the *citizen tuple*.

2.5.1.3 Planner agent properties and decision functions

The properties of the Planner agent are stored in the *planner tuple* and were implemented as follows:

1. *Consistency with MDP*: The Planner's goal on how consistent the proposed developments must be with the town's Municipal Development Plan: no varying from the MDP = 0%, to quite flexible = 20%.
2. *Concern with wetland disturbance*: The Planner's view on the displacement of wetlands to accommodate the proposed development: Concerned = 1, Not concerned = 0.
    a. *Size of wetland moved*: The maximum size of a wetland the Planner is willing to see moved: 1000 m^2 to 40000 m^2.
3. *Density target*: The Planner's goal regarding the density in proposed developments: increase the density = +1, maintain the current level in the bylaws = 0, decrease the density = -1.
4. *Building side-yard setback*: The Planner's goal regarding the distance between the residential buildings as a fire protection measure: increase the current building setback = +1, maintain the current building setback = 0, decrease the current building setback = -1.
5. *Power sharing*: The Planner's view on the weight given to the opinion of the Citizen: 0.1 to 4.
6. *Proposals per year*: The Planner's goal for the number of proposals to review per year: 1 to 10; this goal can also vary based on the housing demand.

The following is a description of how the decision functions of the Planner were implemented:

1. *Opinion function*: The Planner compares, as discussed in section 2.5.1, the appropriate values in the *development tuple* with the land-use allocation in the *Municipal Development Plan (MDP)*, the *housing demand* and the d*evelopment potential* of the town, the land-use bylaws (*density*, *minimum lot area*, and *minimum lot width*), and the first four values in the *planner tuple*.
2. *Decision function*: The Planner weights the *Citizen opinion* based on the *power sharing* property. The sum of the *opinions* of the agents is calculated. If the sum is positive the decision is an approval; if the sum is negative, the Planner requests revisions. A decision of rejection occurs after four revisions.
3. *Revision function*: A request for revisions includes simple recommendations to the Developer regarding the proposed development. These recommendations are based on the *opinions* of the Citizen and the Planner:

   "Increase density" or "Decrease density"

   "Increase lot width" or "Decrease lot width"

   "Increase development time" or "Decrease development time"

   "Increase MR dedication" or "Decrease MR dedication"

   "Follow MDP more closely".
4. *Development potential function*: The Planner evaluates the *development potential* on a yearly basis based on the *development potential* of the previous year, less the

housing market demand for that year, plus the *development potential* of approved residential land development projects whose construction timeline contributes to the *development potential* for that year. As an example, if in the current year a development containing 200 units is approved having a *start* and *finish construction* timeline of one and five years respectively, the development will contribute 50 units per year to the *development potential* starting the next year for the following four years.

2.5.2 Environment implementation

The environment that agents view and act upon was implemented as a raster-based landscape with a 16 m^2 (4 m x 4 m) cell size. The 4 m x 4 m resolution was chosen to accommodate the narrowest strip of land use. The different spatial data types were converted into a series of coincident raster-based maps using the ESRI ArcToolbox Conversion Tools Polygon to Raster and Raster to ASCII. The *cadastral parcel* data were converted into raster format with cell values of the unique parcel identifier. The *land-use map* was converted into raster format with cell values of the land-use type. The *wetland map* was converted into raster format with cell values of the unique wetland identifier. The *gas well locations* were converted into raster format. The *Municipal Development Plan (MDP)* data were stored in a text document. Figure 7 shows a detailed land-use map of the study area corresponding to the raster-based environment of the model.

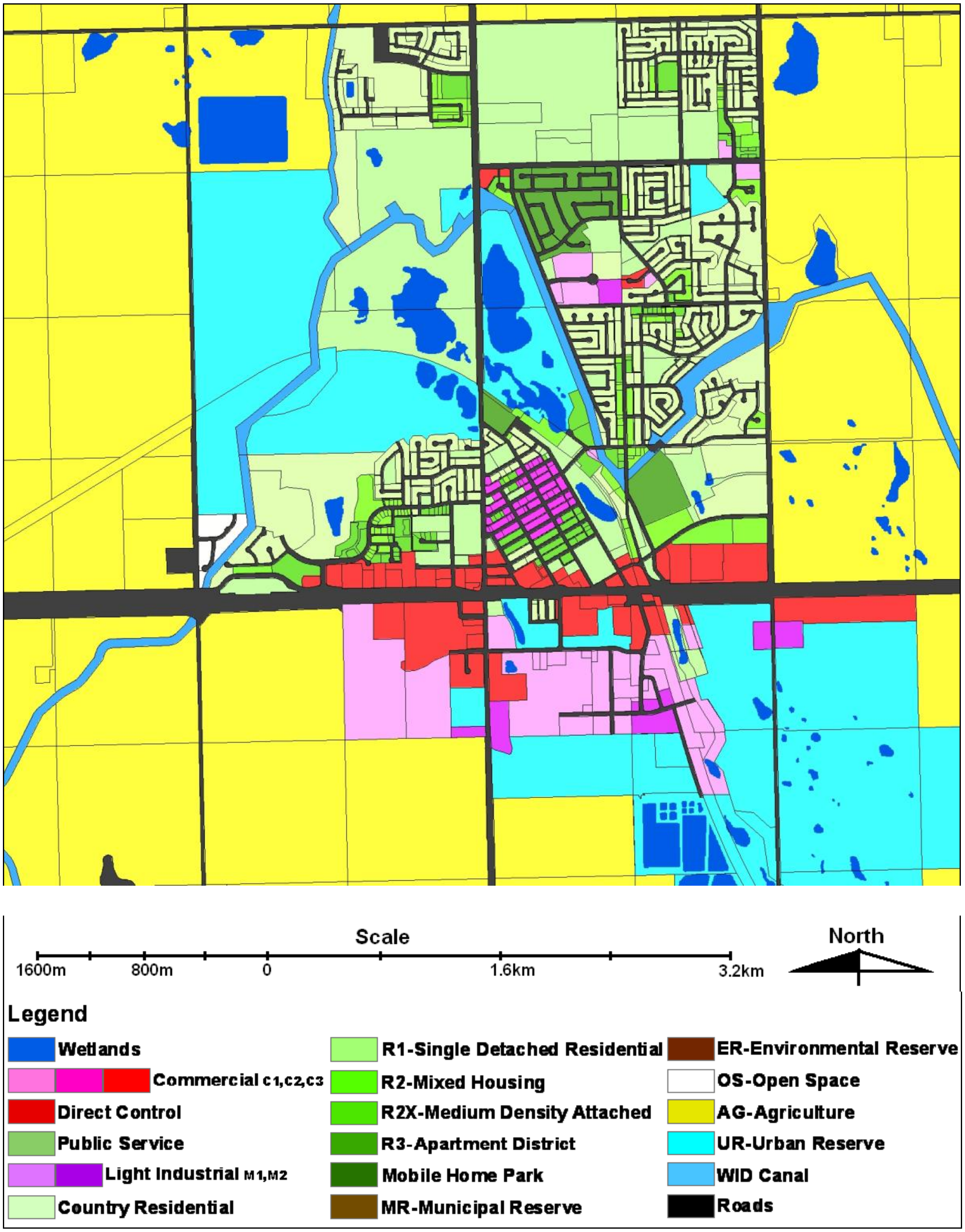

Figure 7: 4 m x 4 m raster-based environment implementation

A process/decision flow diagram (Figure 8) was developed from public documents on the processes published by various authorities: the City of Calgary (2002), the Alberta Land Surveyors' Association (2004), the Town of Strathmore (Town of Strathmore 2006), and the City of Calgary (2008). This decision flow diagram illustrates the decision-making process, the factors influencing decision, and the stakeholder interaction which will be discussed in the following three sections.

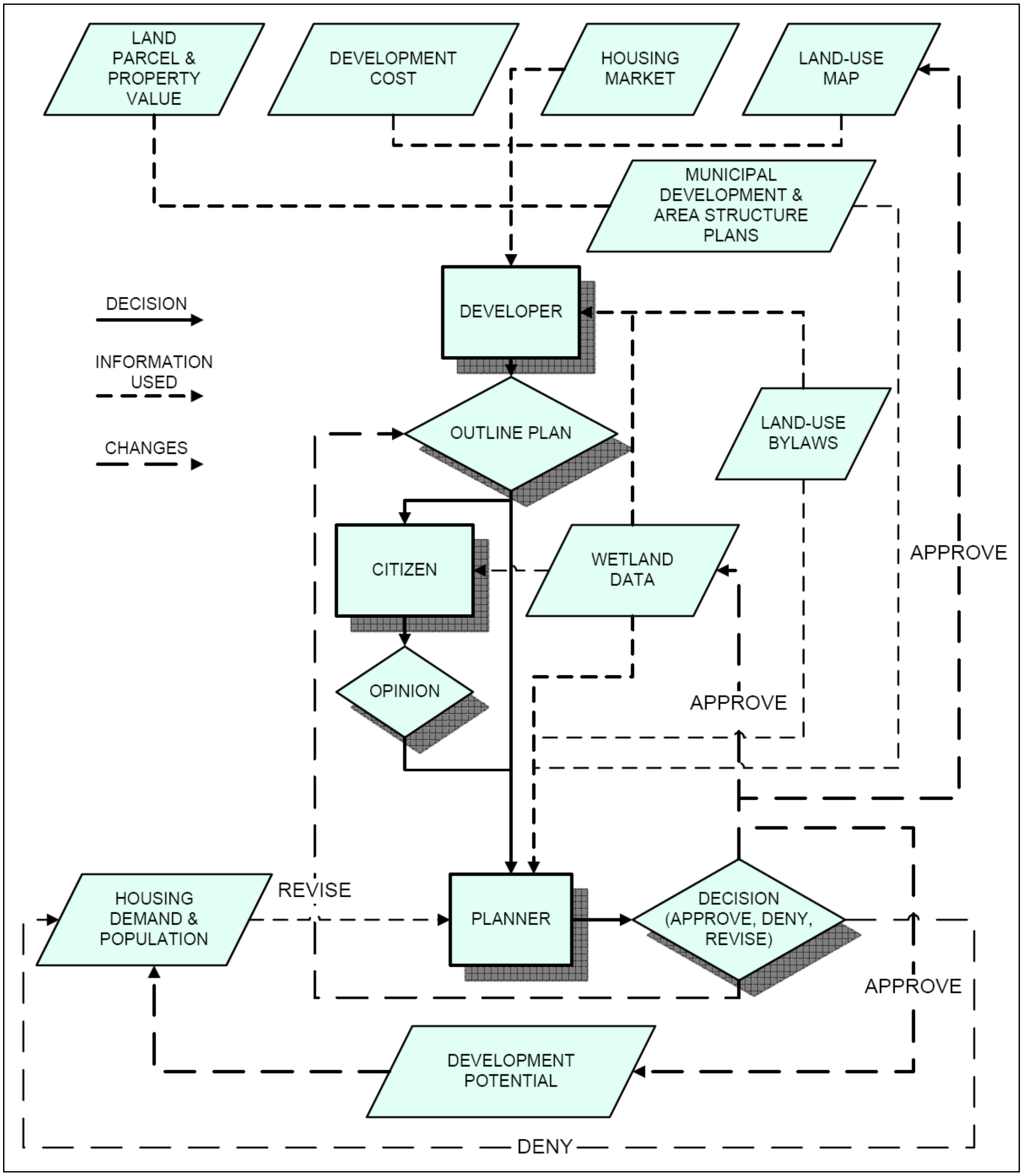

Figure 8: Process/decision flow diagram

2.5.3 Social and economic factors and governmental regulations implementation

The social factors, the economic factors and the governmental regulations were abstracted into model parameters. The following describes how each of the parameters is stored:

1. *Population growth*: variable calculated yearly.
2. *Housing market demand*: variable calculated yearly.
3. *Development potential*: variable calculated yearly.
4. *Housing type market demand*: stored as a constant for each residential housing type.
5. *Land value*: stored as a two dimensional array with the unique parcel identifier.
6. *Construction cost per metre of frontage*: stored as a constant.
7. *Percentage of road dedication*: stored as a constant.
8. *Developed land value*: stored as a constant for each residential housing type.
9. *Construction to retail value multiplier*: stored as a constant.
10. *Cost of moving wetlands*: stored as a constant.
11. *Density*: stored as a constant.
12. *Minimum lot area*: stored as a constant.
13. *Minimum lot width*: stored as a constant.
14. *Percent MR dedication* and *MR compensation*: stored as constants.
15. *Moving wetlands multiplier*: stored as a constant.
16. *Wetland compensation*: stored as a constant.

2.5.4 Agent-agent interaction

Agent-agent communication mimics the steps 2, 4 and 9 of the *land development planning process* (Figure 3):

1. Developer - Planner: a development proposed by the Developer as a *development tuple* is submitted to the Planner and is circulated to the Citizen.
2. Citizen - Planner: the Citizen shares its *opinion* regarding the proposed development with the Planner.
3. Planner - Citizen and Planner – Developer: the decision of the Planner on a proposed development is shared with the Citizen and the Developer. A request for revisions includes the recommendations from the Planner *revision function*.

2.5.5 Agent-environment interaction

Agent-environment interaction occurs on several occasions within the model as environment observations and environment transformations:

1. Observation by the Developer: the Developer observes the wetlands within the land parcel of the proposed development and evaluates them through the Developers *wetland assessment function*.
2. Observation by the Citizen: the Citizen observes the wetlands within the proposed development and generates an *opinion* based on how they are impacted.
3. Observation by the Planner: the Planner observes the wetlands within the proposed development and generates an *opinion* based on how they are impacted.

4. Transformation by the Planner: a decision by the Planner to approve a proposed development generates an immediate transformation of the *land-use map*. The transformation does not physically change the environment but it allows the Developer to begin construction. Greenfield land-use change principles for residential developments, typically followed by developers, were developed for the environmental transformation of the *land-use map* with the assistance of an urban planner and the Civil Engineer. These principles are based on the existing land use, urban reserve (UR) or agricultural (AG), and its change to residential (R1, R2, R2X), municipal reserve (MR), environmental reserve (ER), or open space (OS) based on the land use of parcels adjacent to the proposed land development parcel, and desirability. The land-use transformation for the parcel of land is based on the percentage of each land-use type values contained in the *development tuple* of the approved development, as discussed in 2.5.1.1. Examples of these principles, hard coded as land-use change rules in the model, include: wetland areas are surrounded by a linear park (MR) buffer; low density residential (R1) housing is placed adjacent to the more desirable open space (OS) and park (MR) and are minimized adjacent to the less desirable main thorough fares, commercial, industrial, and higher density residential land-use areas; medium density residential (R2 & R2X) housing is placed adjacent to the less desirable main thorough fares, commercial, industrial, and higher density residential land-use areas; a sizeable area of MR is usually set aside either for

recreational fields or a future public facility (school, church, or community center). The transformation of the *land-use map* then affects the future land use of adjacent proposed developments. The following eight steps describe how the transformation of the *land-use map* occurs within the model using the values contained in the *development tuple*:

1. The wetlands proposed to be moved are amalgamated with the largest existing *wetland* within the proposed development parcel.
2. *Wetland map* areas within the proposed development become Environmental Reserve (ER) cells and are given a 4 m ER buffer of cells.
3. *Gas well locations* are given a 50 m buffer around well sites that must be maintained as Open Space (OS) cells which can be used for recreation purposes.
4. The remaining cells are divided based on the percentage of each land-use type values contained in the *development tuple*.
5. 8 m wide linear parks (MR cells) are generated adjacent to ER, and the WID (Western Irrigation District) canal cells.
6. Medium density residential (R2 cells) is placed adjacent to existing main thorough fares, commercial, industrial, and higher density residential.
7. Low density residential (R1 cells) is placed adjacent to parks and open space and if necessary higher density residential.
8. The remaining land becomes a sizeable area of MR cells.

2.5.6 Spatial and temporal boundaries

The spatial extent of the environment over which the agents make decisions includes all of the newly annexed lands of the Town of Strathmore and 1.6 km of the surrounding Wheatland County.

The Town's Municipal Development Plan attempts to plan for a 30 year future growth, but is typically revised every five to ten years depending on growth rate. The ten year temporal boundary chosen for this study lies within the future plans of the Town's Municipal Development Plan, but only slightly exceeds the MDP revision period so as to give a reasonable but not extreme possible prediction of land-use change. A one year incremental time step was also implemented to update the population growth, housing demand, and housing potential; however the number of developments approved within the one year increment can be varied by the planner agent.

2.6 The computer model

The model was computer coded in the Java programming language for its familiarity and to take advantage of Java's object-oriented features.

2.6.1 User interface

An interface was developed to allow a user to view and modify the initial default property values. The default values in the interface are those developed from the information collected for the Strathbury land development project. The model interface contains three panels: 1) initial conditions, 2) run-time variables, and 3) land-use map.

2.6.1.1 Initial conditions panel

The Initial Conditions panel allows the user to modify the Developer, Citizen and Planner properties, the social and economic factors, and the governmental regulations. The matrix at the bottom of the interface for each agent is the pairwise comparison matrix that allows for the weighting of each agent property, as discussed in 2.5.1.

The following explains the interface that allows the user to set the nine Developer properties as shown in Figure 9:

1. Initial "Happiness" (1-10): to set the initial *happiness* property of the Developer at the start of the model simulation.
2. Yrs Start: to set the number of years to *start construction* property.
3. Yrs Finish: to set the number of years to *finish construction* property.
4. MR (1=make/2=$comp): to set the *park dedication* property.
5. Wetland moved (m^2): to set the s*ize of wetland moved* property.
6. Move wetland (1=y, 0=no): to set the *willingness to move wetlands* property.
7. Extra density <: to set the d*ensity enhancement* property.
8. Mkt:MDP ratio (X/1): to set the *market demand to MDP ratio* property.
9. Profit %: to set the *profit* property.

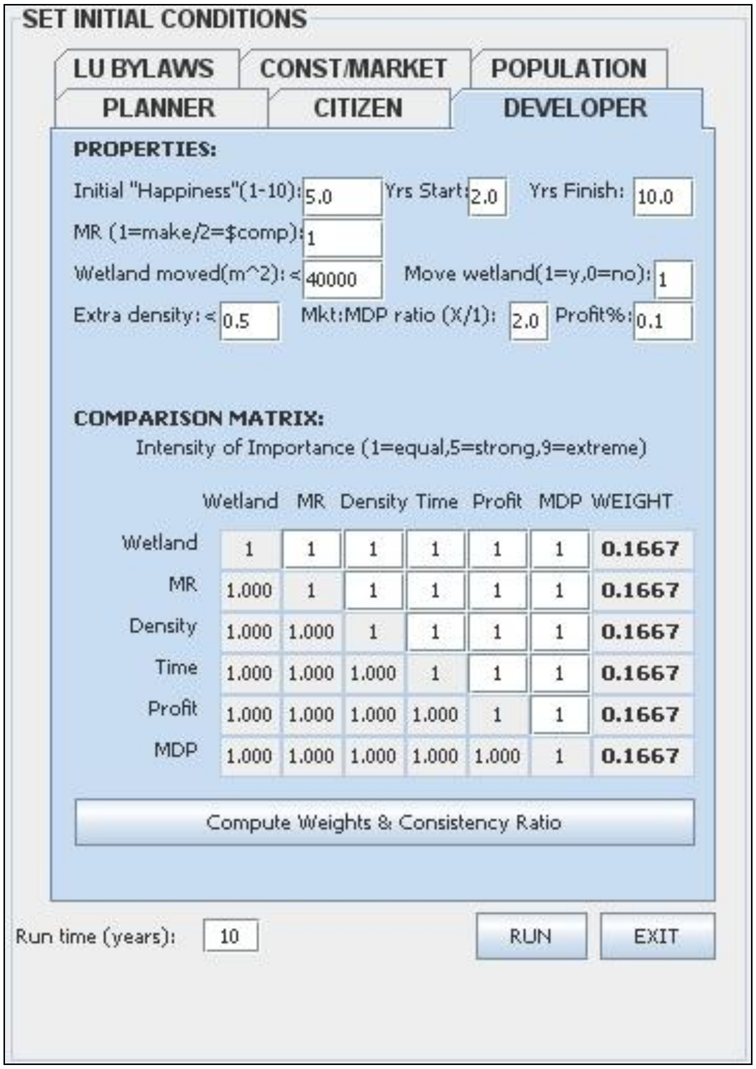

Figure 9: Interface displaying the Developer properties

The interface for the Citizen properties, shown in Figure 10, is similar to the interface for the Developer. It includes two unique properties of the Citizen:

1. Density (+1/0/-1): to set the density target property.
2. Bldg Setback (+1/0/-1): to set the building side-yard setback property.

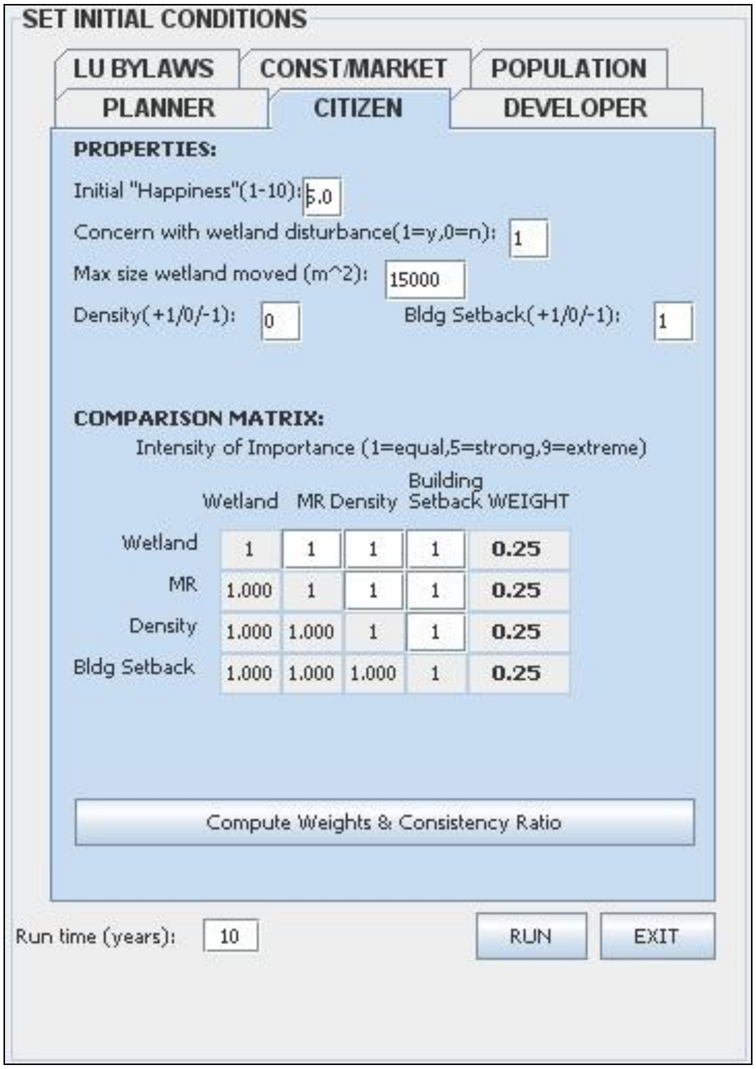

Figure 10: Interface displaying the Citizen properties

The interface for the Planner properties, shown in Figure 11, includes three unique properties:

1. Weight citizen opinion(X/1): to set the *power sharing* property.
2. Proposals/Year: to set the p*roposals per year* property.

3. +/-% MDP: to set the *consistency with MDP* property.

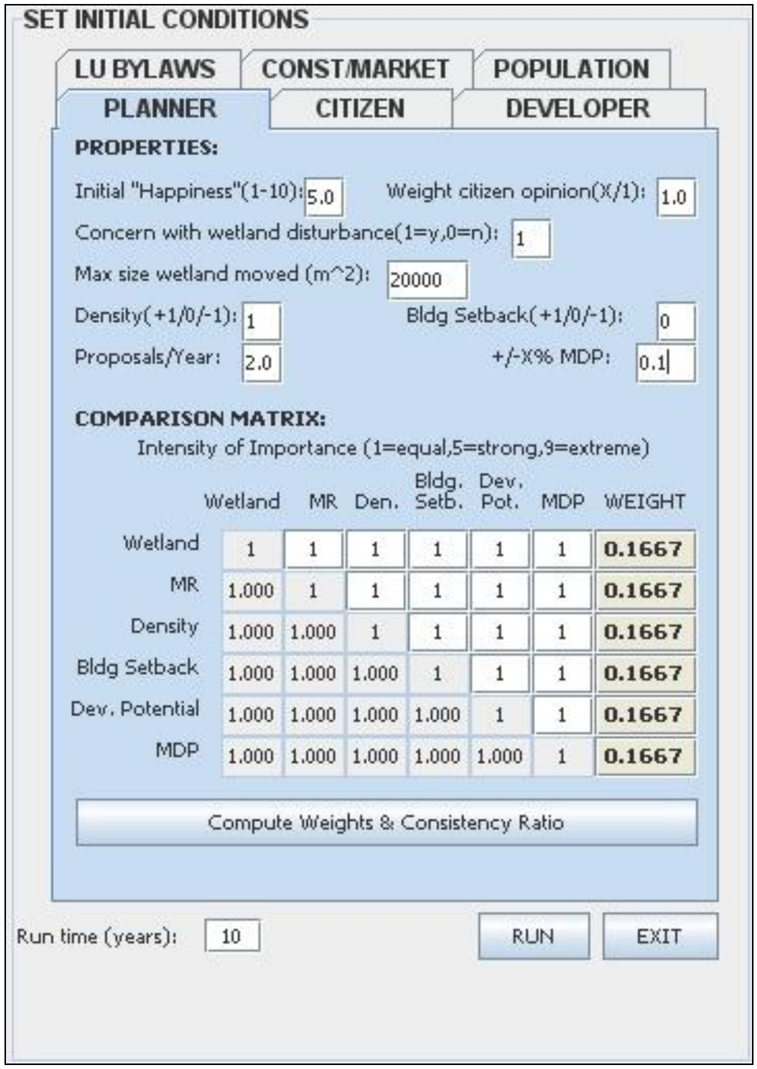

Figure 11: Interface displaying the Planner properties

The following explains the interface that allows the user to set the three social factors (Figure 12):

1. Base housing demand: to set the initial *housing market demand*.

2. Base Development potential: to set the initial d*evelopment potential*.

3. Persons/household: to set the average household size.

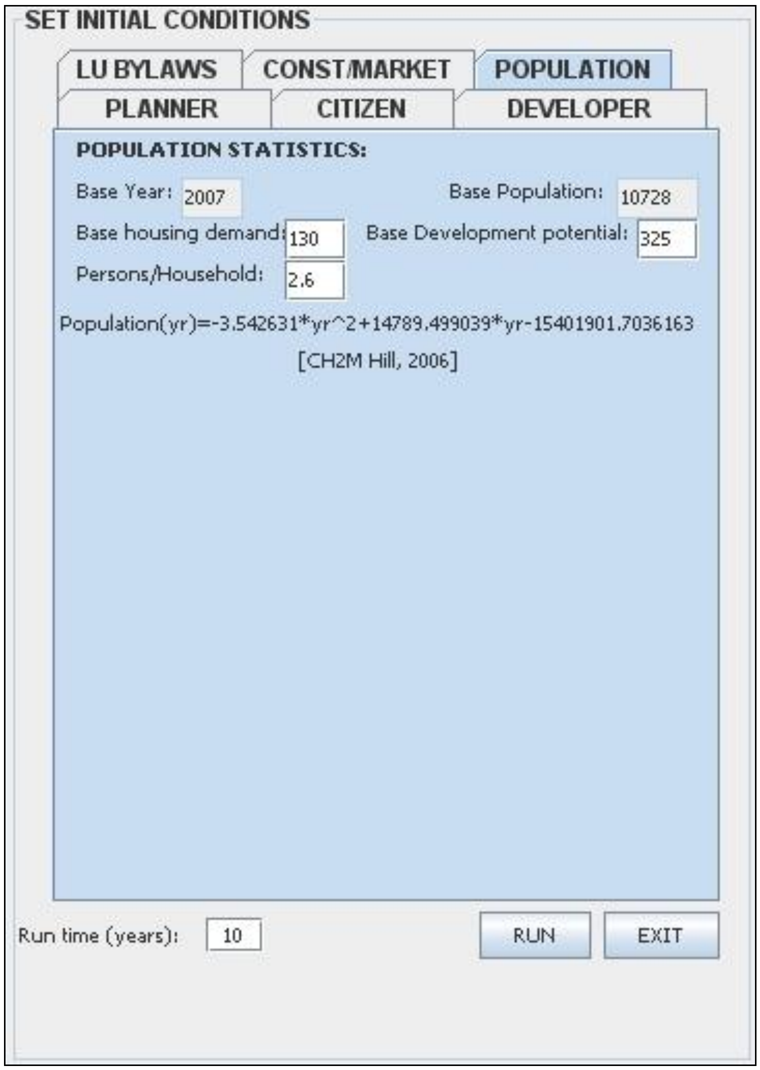

Figure 12: Interface displaying the social factors

The following explains the interface that allows the user to set the 18 economic factors (Figure 13):

1. Const.&Marketing cost ($/m lot frontage): to set the *Construction cost per metre of frontage*.
2. Cost:Market ratio: to set the c*onstruction to retail value multiplier*.
3. % Development road: to set the p*ercentage of road dedication*.
4. and 5. % Wide Road and Wide width: to set the percentage of collector roads and their width.
6. and 7. % Narrow Road and Narrow width: to set the percentage of residential roads and their width.
8. 9., 10. ,11., & 12. R1/R2/R2X market value: to set the *developed land value* for each housing type. The C1, P1, M1 & M2 market values were not used in the model.
13. 14., 15., 16., & 17. R1/R2/R2X % of market: to set the h*ousing type market demand* for each housing type.
18. Wetland moving cost ($/hectare): to set the w*etland compensation*.

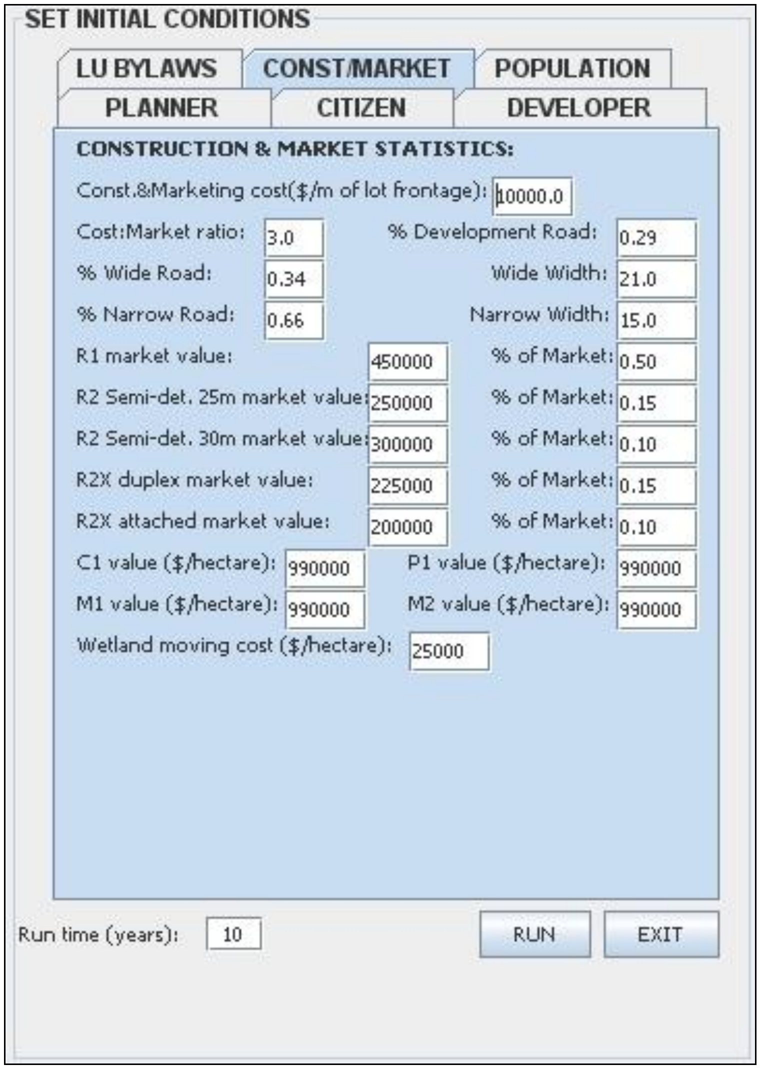

Figure 13: Interface displaying the economic factors

The following explains the interface that allows the user to set the 14 governmental regulations (Figure 14):

1. Density: to set the d*ensity* regulation.
2. Move wetland multiplier: to set the m*oving wetlands multiplier* regulation.

3. % MR: to set the *percent MR dedication* regulation.
4. MR compensation ($/hectare): to set the *MR compensation* regulation.
5. 6., 7., 8., & 9. R1/R2/R2X lot area: to set the *minimum lot area* regulation for each housing type.
10. 11., 12., 13. & 14. R1/R2/R2X lot width: to set the *minimum lot width* regulation.

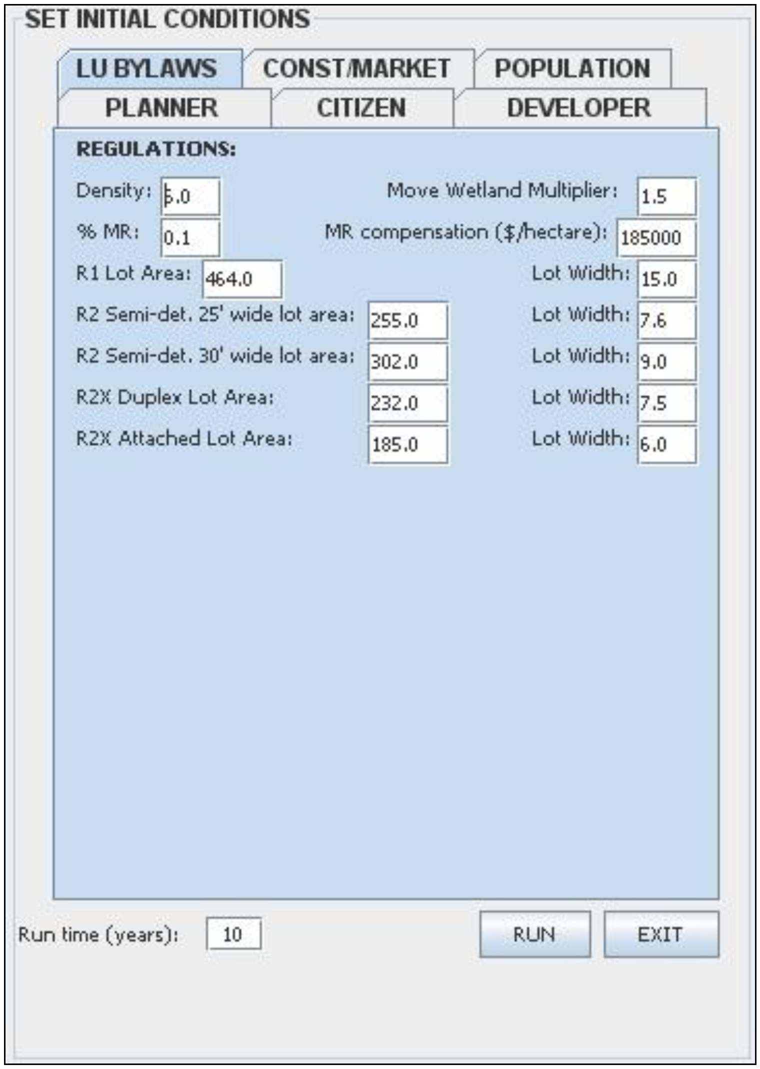

Figure 14: Interface displaying the governmental regulations

2.6.1.2 Run-time variables panel

Figure 15 is the run-time variables panel which displays the decisions of agents as the model runs, including the proposed development that has some values that are contained in the *development tuple*, the Citizens and Planners *opinions*, the *happiness* of each agent and the Planner’s decision.

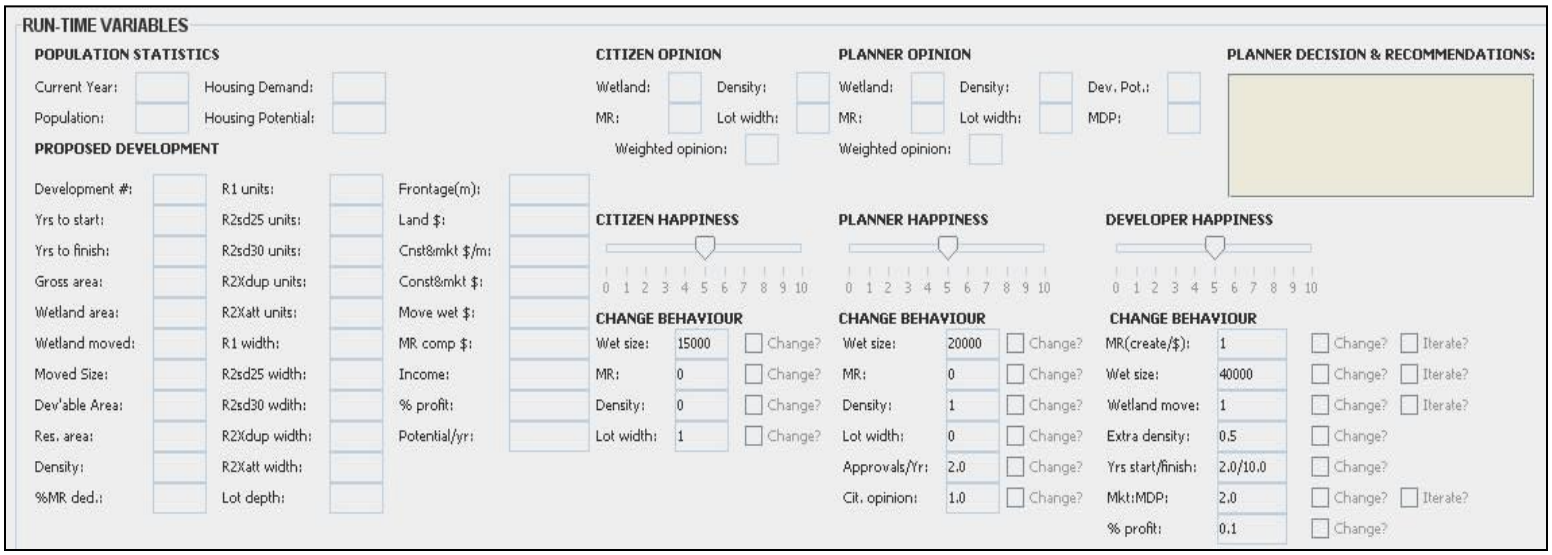

Figure 15: Interface displaying the run-time panel

The following six figures show the details of the run-time variables panel. Figure 16 shows the population and housing social factors.

POPULATION STATISTICS

Current Year:	2007	Housing Demand:	130
Population:	10728	Housing Potential:	325

Figure 16: Run-time detail: population and proposed development

Figure 17 contains the development calculations of the Developer and the development proposed for a parcel of land; these are some of the values contained in the *development tuple* discussed in section 2.5.1.1.

PROPOSED DEVELOPMENT

Development #:		R1 units:		Frontage(m):	
Yrs to start:		R2sd25 units:		Land $:	
Yrs to finish:		R2sd30 units:		Cnst&mkt $/m:	
Gross area:		R2Xdup units:		Const&mkt $:	
Wetland area:		R2Xatt units:		Move wet $:	
Wetland moved:		R1 width:		MR comp $:	
Moved Size:		R2sd25 width:		Income:	
Dev'able Area:		R2sd30 wdith:		% profit:	
Res. area:		R2Xdup width:			
Density:		R2Xatt width:			
%MR ded.:		Lot depth:			

Figure 17: Run-time interface detail: proposed development

Figures 18 and 19 display the Citizen, the Planner and the Developers goal parameter values and their *happiness*. As mentioned in section 2.5.1, an attempt was made to implement agent behavioural change in the model; the disabled check boxes in the run-time variables window are evidence of this attempt, the problems that were encountered are discussed in the conclusion.

Figure 18: Run-time interface detail: citizen and planner happiness, and properties

Figure 19: Run-time interface detail: developer happiness, and properties

Figures 21 and 21 show the Citizen and the Planner *opinion* of each proposed development, the weighted opinion calculated by the agent (as discussed in 2.5.1) and used by the Planner in his decision function (as discussed in 2.5.1.3), and the Planner's decision or recommendation.

Figure 20: Run-time interface detail: citizen and planner opinion

Figure 21: Run-time interface detail: planner decision and recommendations

2.6.1.3 Land-use map panel

The land-use map panel displays the changing land use as the development proposals are approved (Figure 22).

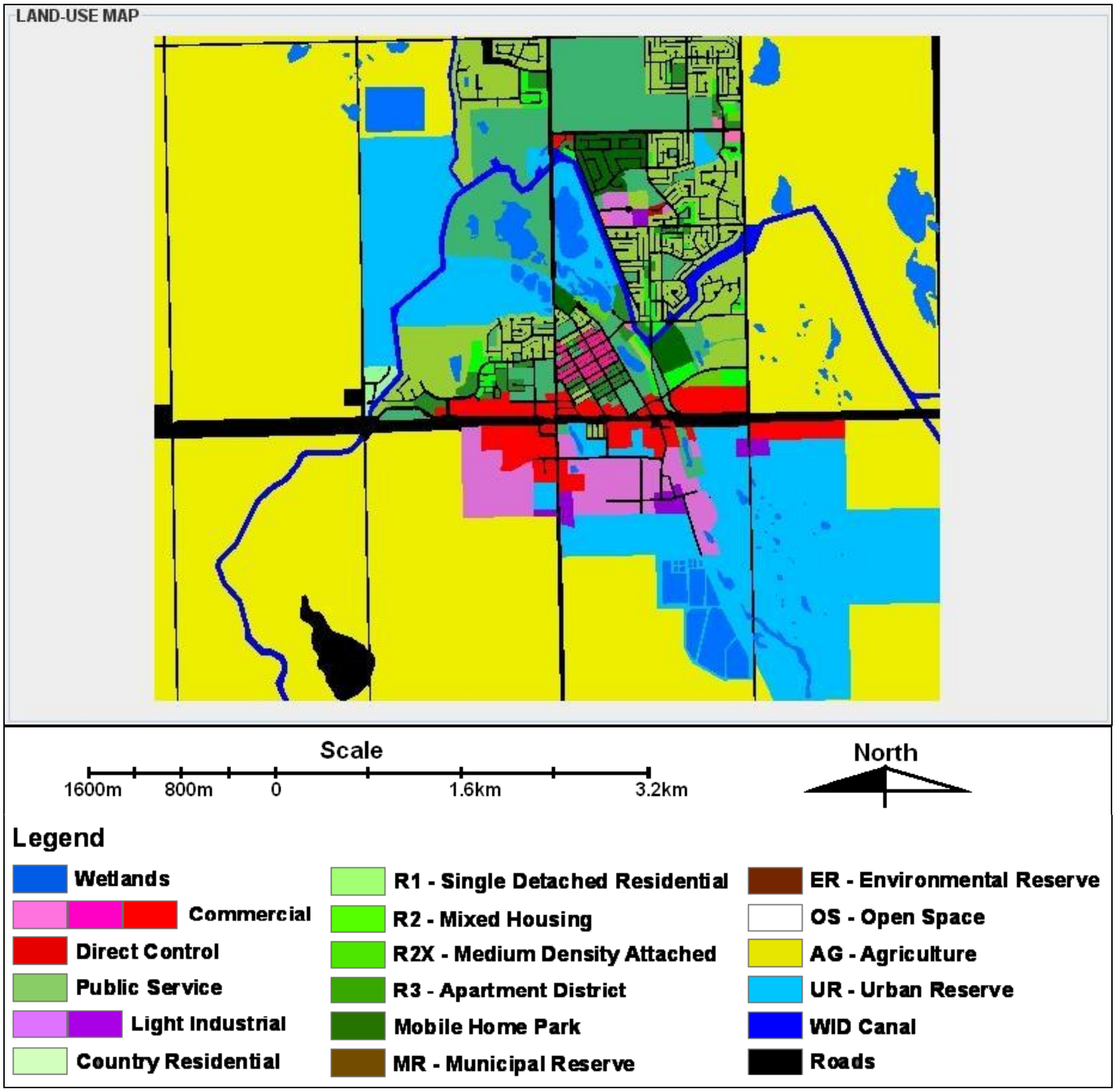

Figure 22: Interface displaying the land-use map panel

2.6.2 The computational logic

The following is the computational steps followed by the software when simulating the *land development planning process* for a residential land development.

1. The software reads in the raster *land-use map*, the *wetland map*, and the *gas well locations*, the *cadastral parcel* sequencing, the *Municipal Development Plan (MDP)* information, and the *land value* data.
2. The parameters of the model initialization are populated with the default values including: the agent properties, the social factors, the economic factors, and the governmental regulations. The default values are discussed in the following section.
3. The user is given the chance to change the model parameters.
4. The simulation year starts at 2007.
5. The next cadastral parcel in the sequencing, as discussed in 2.4.2, is observed by the Developer. The Developer performs the following functions, as discussed in section 2.5.1.1: *wetland assessment*, *gross developable area*, *municipal reserve*, *net developable area*, *housing allocation*, *lotting*, and *profit determination*. A *development tuple* is produced and the Developer generates an *opinion*.
6. The Citizen performs its *opinion function* and shares its *opinion* with the Planner, as discussed in section 2.5.1.2.
7. The Planner performs its *opinion* and *decision function* and if required a *revision function*, as discussed in section 2.5.1.3. Based on the decision, the happiness of the Developer, Citizen and Planner are updated.
8. If the Planner decision is an approval, an environmental transformation to the *land-use map* occurs, as discussed in section 2.5.5.

9. If the Planner has not met the *proposals per year* approved property, steps 5 through 9 are repeated.
10. If the Planner has met the *proposals per year* approved property, the Planner's *development potential function* is performed.
11. Assuming that the maximum simulation time of10 years has not been reached, the year is iterated and steps 5 through 11 are repeated.

2.7 Model calibration and verification

The calibration and verification of the model was done by comparing the values of the variables in the model run-time panel to the values in the development summary table of the Strathbury Outline Plan and Land-use Redesignation application. It was also done by comparing the model land-use map results to the actual land-use maps generated for the Strathbury Outline Plan and Land-use Redesignation application. Comparisons were also made between the model run-time variables and two pre-application development Strathbury concepts, produced by the developer. The development concepts proposed slightly different densities, wetland displacement options and percentages of each housing type.

Model verification is the testing of the computational logic of the model. The majority of computation occurs in the development proposal functions of the Developer (Section 2.5.1.1) and the environmental transformation (Section 2.5.5). These computations were checked by walking through each calculation of the model and step by step comparing the calculated values to values calculated independently using a spreadsheet. The density, wetland displacement and housing percentage model parameters were initialized with the same inputs as each of the Outline Plan application and the development concepts. The computational logic of the model was checked against the values in the spreadsheet. The results of the spreadsheet were compared to the development summary table of the Strathbury Outline Plan and Land-use Redesignation application. Verification of the land-use allocation of the cellular model component was done by comparing the raster cell counts calculated by the model for each land-use type within a redesignated land parcel to values calculated independently using a spreadsheet. The results of the spreadsheet were compared to the percentages of land-use type proposed in the development summary table of the Strathbury Outline Plan and Land-use Redesignation application.

Calibration is the procedure that ensures that the model correctly simulates the real-world system studied by inputting real-world model initialization parameter values and comparing the model results to known real-world results (Castle & Crooks 2006). The model in this research was calibrated using agent goal parameter values, spatial datasets, social factor values, economic factor values, and governmental regulation values from the data that were collected from the stakeholders in the Strathbury land development project, as discussed in section 2.4. The model was initialized using these default parameter values. The happiness property for each agent was initialized with a default value of 5, corresponding to moderately happy. Although the pairwise comparison matrix that enables weighting of agent properties was implemented in the model, as discussed in 2.5.1, insufficient data were collected from the stakeholders for the Strathbury project to populate this matrix. Therefore all agent properties were given an equal weight. The agent goal parameters were initialized as follows:

Developer goal parameters:

- Construction timeline: begin construction in 2 years and finish in 10 years.
- Prefers to provide space for parks rather than having monetary compensation.
- Willing to move wetlands up to 4 hectares in size to suit the development.
- Tries to increase density by 0.5 units per acre.
- Housing market demand to Municipal Development Plan ratio is 2:1.
- Wants a 10% rate of return on the investment in the project.

Planner goal parameters:

- Gives equal weight to the opinion of the citizens regarding the proposed development during the decision-making process as a power sharing contribution.
- Is concerned with the movement of significant wetlands and would not like wetlands larger than 2 hectares to be displaced.
- Would like to increase the current residential density.

- Would like to maintain the current building setback per the zoning bylaws.
- Is quite concerned with the development potential; therefore it is given a greater weight.
- In the past, has approved an average of two large development proposals per year which has kept up with housing demand.
- The consistency with the MDP is only +/-5% since the MDP values have been revised to match the more recently adopted Strathmore Lakes Estates Area Structure Plan (ASP).

Citizen goal parameters:

- Is concerned with the displacement of significant wetlands and would not like wetlands larger than 1.5 hectares to be moved.
- Would like to maintain the current density goal per acre per the zoning bylaws.
- Would like to increase the current building setback per the zoning bylaws, because of a fire hazard concern.

The social factors were initialized from the values discussed in section 2.4.3, the economic factors were initialized from the values discussed in section 2.4.4, and the governmental regulations were initialized from the values discussed in section 2.4.5.

The calibration was done by comparing the results of the model simulation using the Strathbury parameter values with the actual data contained within the Strathbury Outline Plan and Land-use Redesignation application generated by the developer, and their sub-consultants. This involved comparing values contained in the run-time proposed development interface (Figure 17) to values contained in the development summary table within the actual Outline Plan and Land-use Redesignation application, including: the total area, environmental reserve area, developable area, the total number of residential units, and the number of residential units of each type. The results of the raster land-use map produced by the model were also compared to the land-use map within the Outline Plan and Land-use Redesignation application. The calibration results will be discussed in Chapter three.

2.8 Development scenarios

The following five scenarios were run with the model over a period of ten years, each having different initial conditions; the results will be discussed in the following chapter:

1. The “business as usual” (BAU) scenario assumes that the regulations, goals of the stakeholders, and decisions made in the Strathbury project are typical and that decisions will continue to be made in this manner.
2. The “reduction in development approvals per year” scenario only permits one development approval per year controlling the development potential and the rate of growth.

3. The “increase in density” scenario modifies the Land-use Bylaws and Municipal Development Plan allowing the developer to propose a higher housing density.
4. The “change in market housing demand” scenario accounts for a prediction by Ewing (2007), that the demand for residential housing types is going to change over with the retirement of baby boomers, through changing the Land-use Bylaws, Municipal Development Plan and the market demand for smaller housing types.
5. The “sustainable development” scenario controls the development rate, assumes an increased demand for smaller housing types, decreases the areas of road infrastructure scarring the environment, and does not allow the disturbance of wetlands.

2.9 Validation of the results

The results of the model were validated using a method called “face validation” (Ligtenberg et al. 2001). This method asks persons, such as professional planners, who are considered to be experts in the subject matter to compare the simulation results to their knowledge of the real-world system and make judgements on the results.

Chapter Three: Result Analysis

This chapter is divided into three sections. The first section discusses the results of the calibration and verification of the model as it simulates the proposed Strathbury development. The second section examines and analyzes each of the six development scenarios introduced in the previous chapter. The third section addresses the validation of the model results for the six development scenarios.

3.1 Calibration and verification results: the Strathbury development

The following six figures (Figures 23, 24, 25, 26, 27, and 28) show model run-time variables and results of the baseline calibration for the Strathbury land parcel. Figure 23 is the resulting development proposed by the Developer for Strathbury. The following describes each value in the interface:

- Development # = 2.1: parcel 2 (Strathbury), first attempt.
- Yrs to start = 2, Yrs to finish = 10: the construction timeline.
- Gross Area = 797904: the area of the parcel in m^2.
- Wetland area = 164400: the area of wetland within the land parcel in m^2.
- Wetland moved = 36832: the area of wetland proposed to be displaced in m^2.
- Moved size = 55248: the area of wetland to be restored in m^2.
- Dev'able area = 593586, Res. area = 593586: the remaining developable and residential area in m^2.
- Density = 6.5: the proposed residential density in units/acre.

- MR ded. = 0.1: the proposed amount of Municipal Reserve to be dedicated, 10% of the developable area.
- R1 units = 305, R2sd25 units = 211, R2sd30 units = 202, R2Xdup units = 161, R2Xatt units = 76: the proposed number of units of each residential housing type. When converted into percentages: 32% R1, 43% R2 and 25% R2X, they adhered to the MDP and ASP regulations within the leniency given: 30% R1, 45% R2 and 25% R2X.
- R1 width = 15, R2sd25 width = 7.6, R2sd30 width = 9, R2Xdup width = 7.5, R2Xatt width = 6: the proposed width of each residential housing lot in m.
- Lot depth = 37.54: the average proposed lot depth in m.
- Frontage = 20722: the total lot frontage based in the number of each residential lot type and its corresponding width in m.
- Land = 7689489, the total cost for the land in $.
- Cnst&mkt $/m = 11000, the construction and marketing cost for a metre of frontage.
- Const&mkt $ = 227946101, the total construction and marketing cost in $.
- Move wet $ = 92080, the construction cost for displacing and restoring the wetlands in $.
- Income = 301589620, % profit = 28, the total income and percent profit based on current market housing prices and current construction cost.

PROPOSED DEVELOPMENT

Development #:	2.1	R1 units:	305	Frontage(m):	20722
Yrs to start:	2.0	R2sd25 units:	211	Land $:	7689489
Yrs to finish:	10.0	R2sd30 units:	202	Cnst&mkt $/m:	11000.00
Gross area:	797904	R2Xdup units:	161	Const&mkt $:	227946101
Wetland area:	164400	R2Xatt units:	76	Move wet $:	92080
Wetland moved:	36832	R1 width:	15.00	MR comp $:	0
Moved Size:	55248	R2sd25 width:	7.60	Income:	301589620
Dev'able Area:	593586	R2sd30 wdith:	9.00	% profit:	28
Res. area:	593586	R2Xdup width:	7.50		
Density:	6.500	R2Xatt width:	6.00		
%MR ded.:	0.100	Lot depth:	37.54		

Figure 23: A summary of the Strathbury development proposed by the Developer

The following summarizes the values of the model variables versus the values contained in the Outline Plan and Land-use Redesignation application; the values (model vs. application) are within 0.1 to 3% of each other, a reasonable consistency for this research:

- Gross area: 797904 m^2 vs. 797229 m^2
- Environmental reserve (ER): 201232 m^2 vs. 203557 m^2
- Developable area: 593586 m^2 vs. 593673 m^2
- Number of residential units: 955 units vs. 954 units
- Number of R1 units: 305 units (32% of the total) vs. 315 units (33% of the total)
- Number of R2 units: 413 units (43% of the total) vs. 410 units (43% of the total)
- Number of R2X units: 237 (25% of the total) units vs. 229 units (24% of the total)

Figure 24 shows the *opinion* of the Citizen and the Planner based on the results of their *opinion functions*, as discussed in 2.5.1. The Citizen has a low opinion on the proposed density and displaced wetlands, whereas the Planner has a high opinion on the proposed density and the development potential; both of these seem to be appropriate based on the information gathered from the stakeholders for the Strathbury project as discussed in section 2.4.

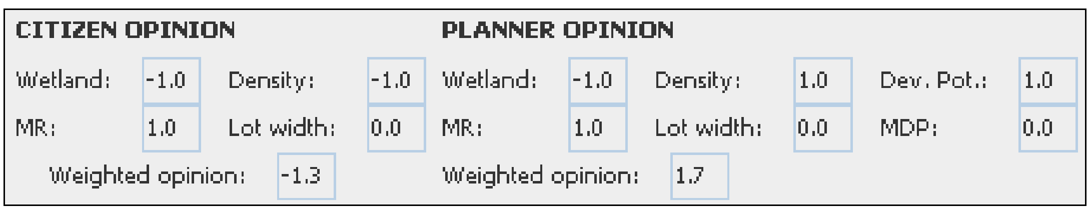

Figure 24: Opinions of the citizen and planner on the proposed Strathbury development

Figure 25, is the resulting *decision* by the planner based on its *decision function*.

Figure 25: The decision of the planner regarding the Strathbury Outline Plan and Land-use Redesignation application

Figure 26 shows the existing undeveloped Strathbury parcel, highlighted in red, designated as urban reserve (UR), and containing eleven wetlands. A road splits the east and west portions of the parcel. The west portion is bounded by the Western Irrigation District (WID) Canal on the west, public service to the north, and residential to the south. The east portion contains more wetlands; it is bounded by wetlands to the north, the WID Canal to the east and residential areas to the south.

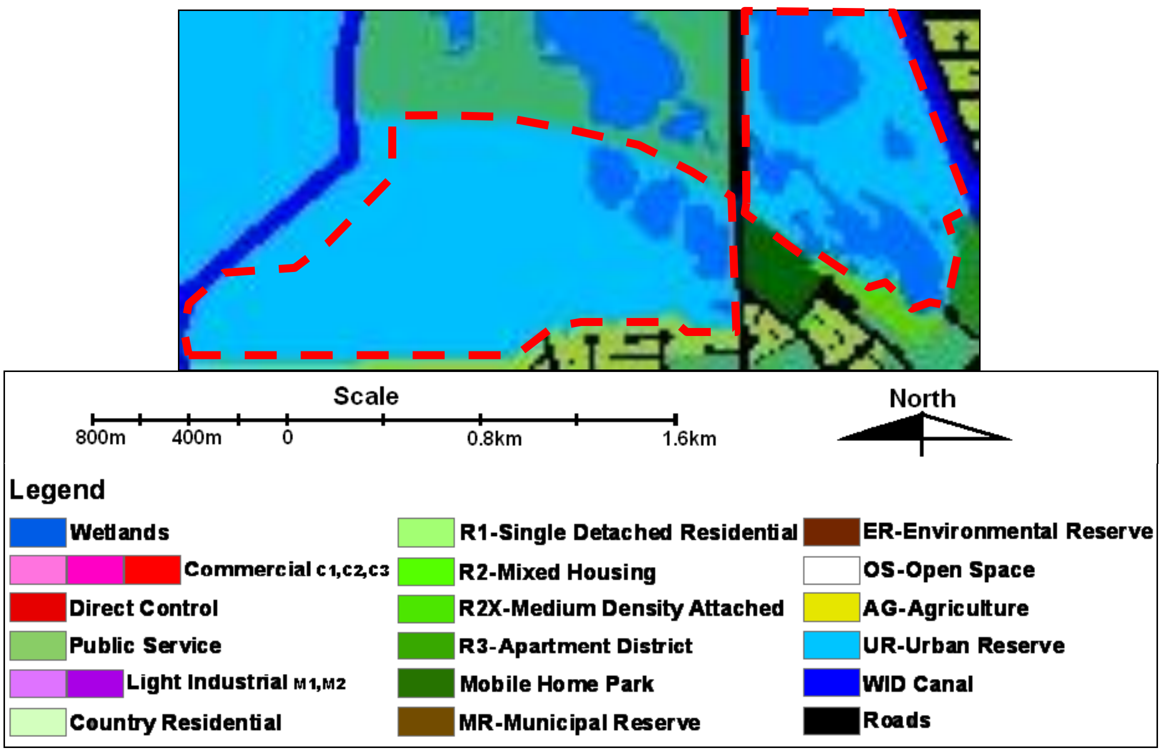

Figure 26: Model land-use map prior to the approval of the Strathbury development

Figure 27 is the model results of the approved Strathbury land-use redesignation to residential, environmental reserve, and municipal reserve and the displacement and consolidation of eight wetlands.

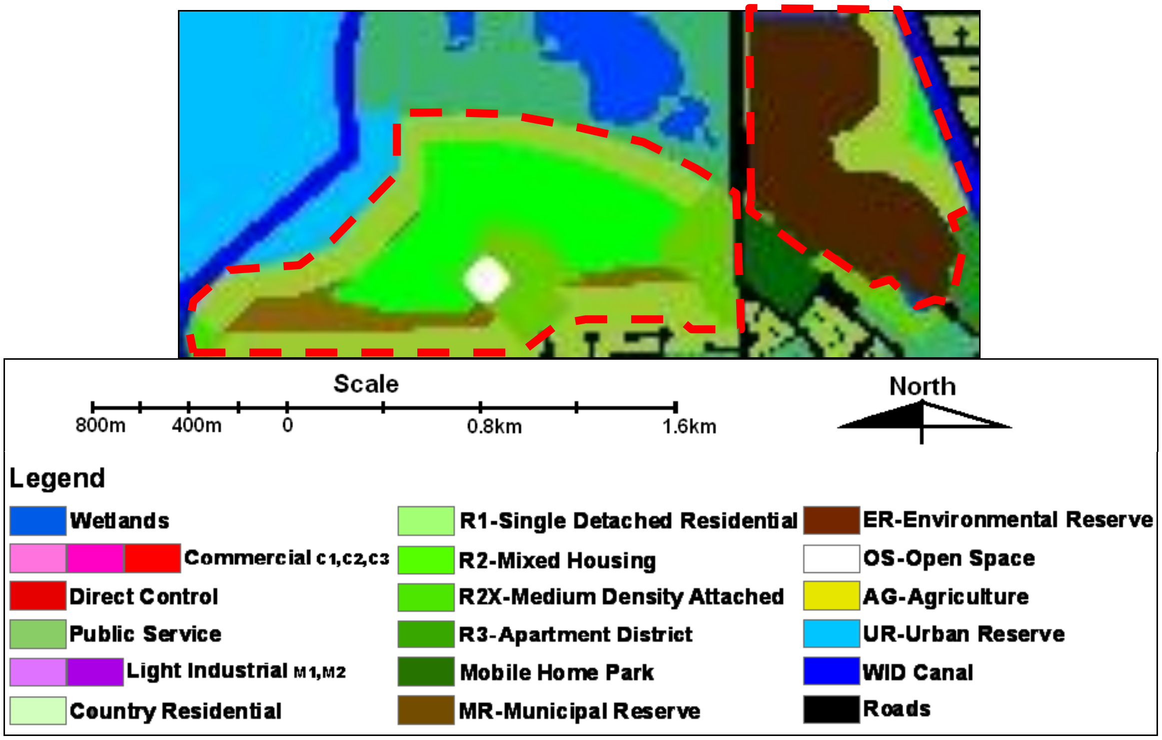

Figure 27: Model land-use map after the approval of the Strathbury development

Figure 28 is the actual land-use allocation map contained in the documents for the Strathbury Outline Plan application. As discussed previously the percentage of each land-use type allocated by the model quantitatively matches the values contained in the actual Strathbury Land-use Redesignation and Outline Plan application. However, due to the difference between the principles followed by the actual Strathbury developer when allocating the land-use and the land-use transition rules hard coded in the model, as discussed in section 2.5.5, the land-use patterns are different.

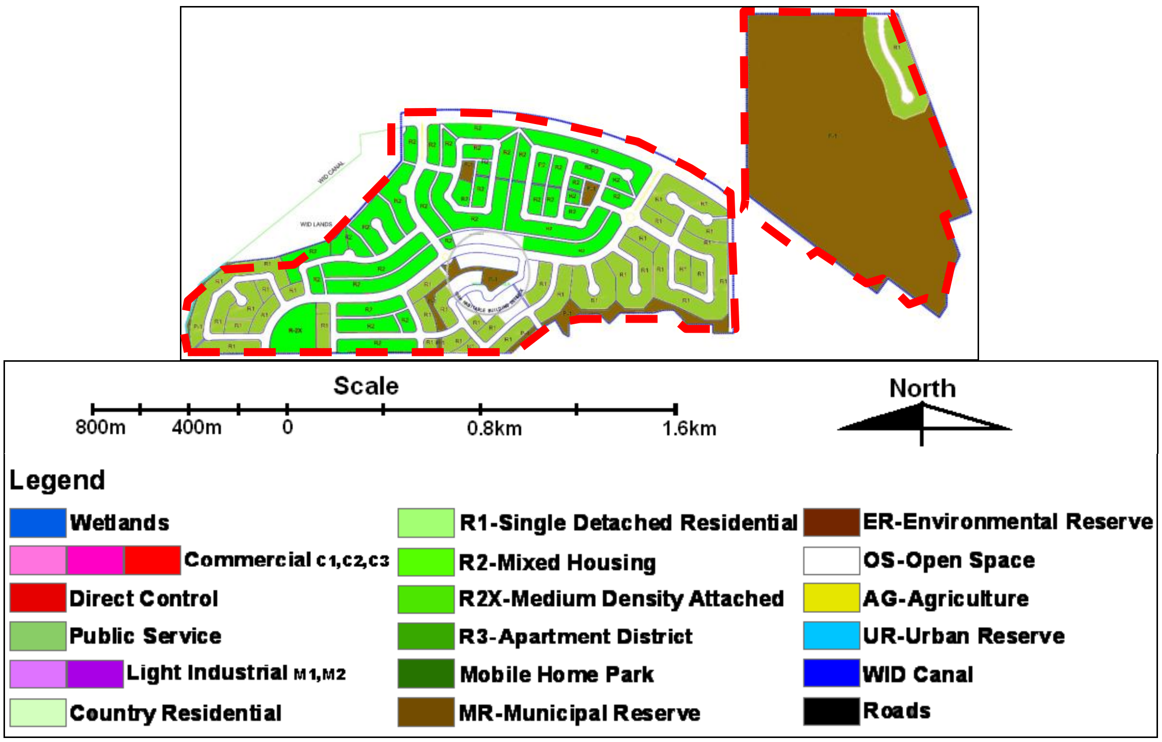

Figure 28: Actual land-use map from the Strathbury Outline Plan and Land-use Redesignation application

Based on the results of the calibration, it appears that the model produces results reasonably comparable to the actual documents and plans of the Strathbury residential land development project. In general, the model adequately mimics the Strathbury

Outline Plan and Land-use Redesignation application by the WestCreek, the opinion of the citizens, the decision by the Town to approve the Redesignation, and ultimately the land use change.

3.2 Model run results

When analyzing the raster maps in the following scenarios one must keep in mind that the model does not generate road infrastructure patterns. Therefore, when viewing the land-use allocation generated by the model and the existing land-use allocation, one must visually fill in either half of the existing minor road infrastructure with its adjacent land use creating a more connected land-use map allocation similar to that generated by the model, or one can visualize a similar road network within the model generated land-use map. In doing this, one can see similar land-use area allocation but in some situations dissimilar land-use pattern allocation.

3.2.1 Business as usual scenario (BAU)

The "business as usual" (BAU) scenario is based on an initialization from the Strathbury development goals and regulations and projecting into the future. Due to the age of the MDP the Developer is given additional leniency on the *Consistency with MDP* to 10%. Initially the Planner has a *happiness* of 9.0 to 10.0, continuously approving redesignation applications, trying to keep up with the *housing demand* and increasing the *development potential*. On three occasions the Citizen gives the proposed developments a negative *opinion* due to wetlands being displaced, but in general has a *happiness* of 4.0 to 6.0. During the years of approvals, the Developer has a *happiness* of 8.0 to 9.0 making profit. During year 6, the Planner requests a “decrease in development time”, speeding up the potential for new housing, increasing the Developer *happiness* to 10.0. By year 9 the *development potential* has surpassed the *housing demand* and in the subsequent years the Planner requests revisions to “increase the development time”, slowing the potential for new housing, decreasing the Developers *happiness* to 4. By the end of the simulation time, the *development potential* is 170% that of the *housing demand*.

Figure 29 shows the land-use change over the ten year simulation period based on the BAU goals, regulations, standards and market parameter initialization. During the ten years of simulation, land-use change occurs over approximately 280 hectares contained within 17 land parcels. The percentage allocation of each residential land-use type follows the MDP regulations and *Housing type market demand*, and *Market demand to MDP ratio* of the Developer as expected: 47% R1, 23% R2 and 30% R2X.

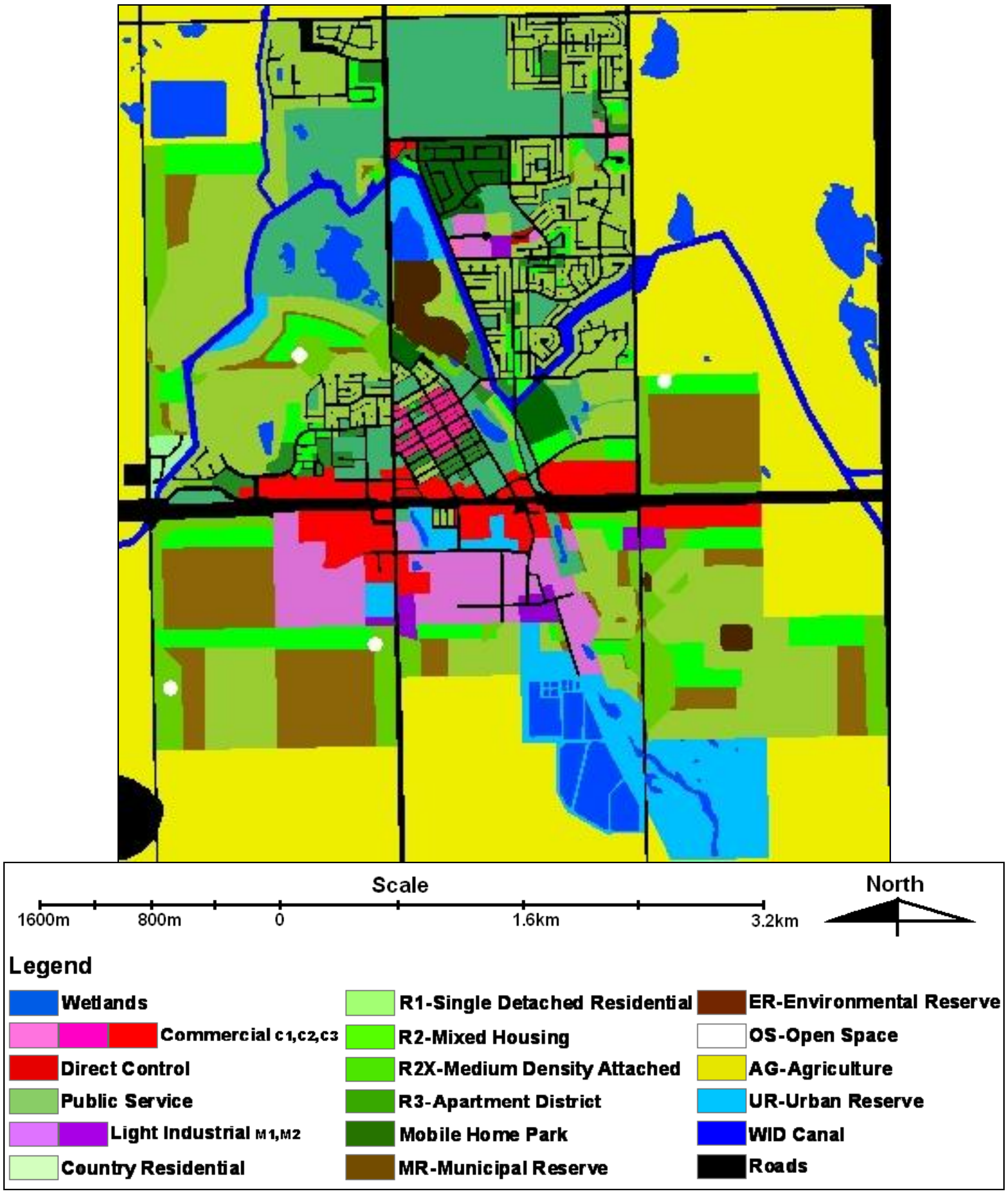

Figure 29: Land-use map obtained with the business as usual scenario

3.2.2 Reduction in development approvals per year scenario

This model simulation starts with the Planner *proposals per year* reduced to one. During the simulation, the Planner and Developer maintain a *happiness* of 9.0 to 10.0, the Planner again continuously approving redesignation for proposed developments, trying to keep up with the *housing demand* and increasing the *development potential*, and the Developer content having all proposed redesignation applications approved. The Citizen has a slightly higher *happiness*, of 5.0 to 6.0, than in the BAU scenario, having fewer wetlands impacted. Over a ten year period, this scenario resulted in the *development potential* being 17% less than the *housing demand*.

Figure 30 shows the land-use change over the ten year period based reduction in development approvals per year. Compared to the BAU scenario, the impact on land use occurs over a much smaller area, approximately 174 hectares contained within 10 land parcels; however, as expected, the land-use allocation and patterns are the same.

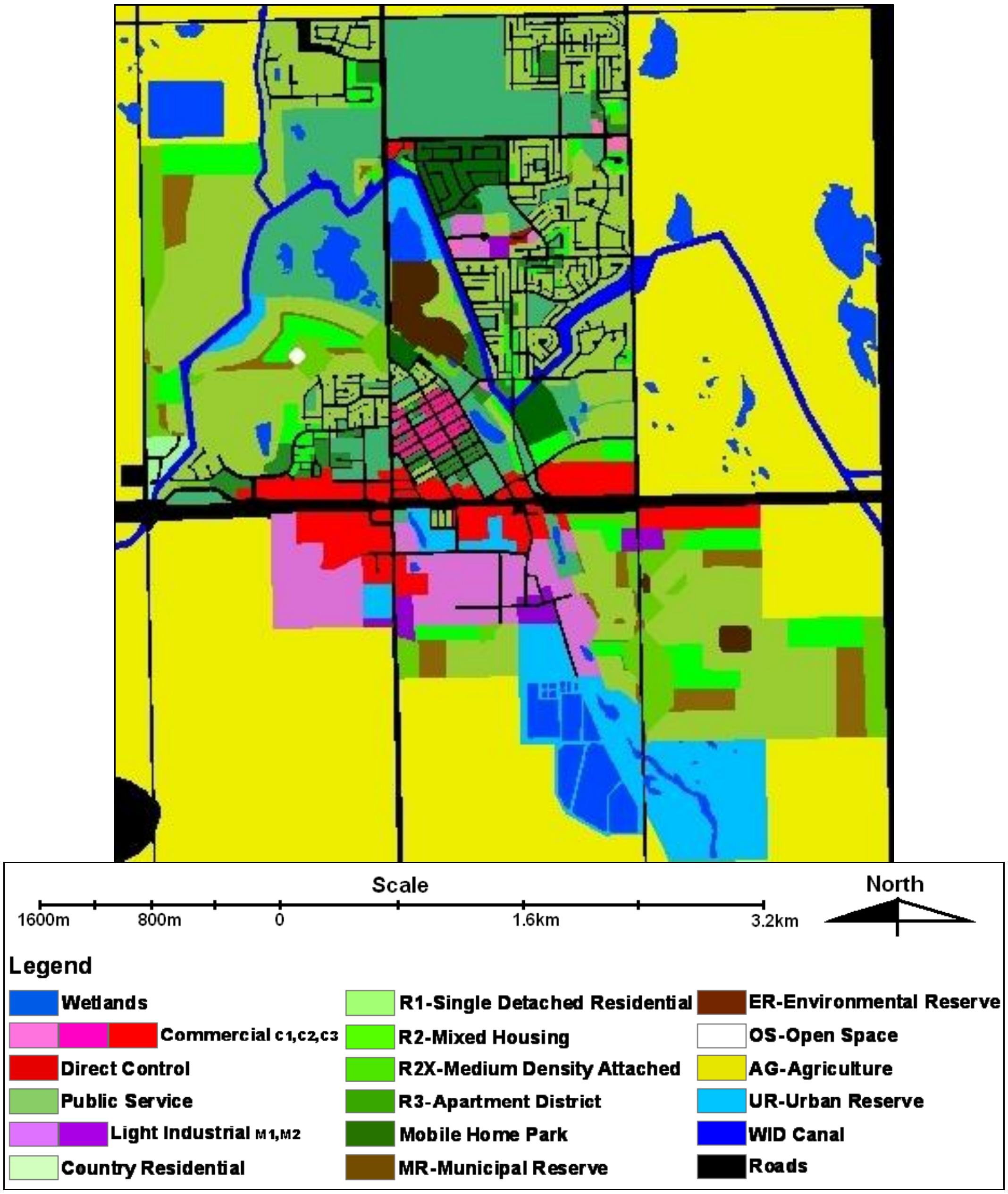

Figure 30: Land-use map obtained with the reduction in development approvals scenario

3.2.3 Increase in density scenario

This model simulation is initialized with a bylaw regulation *density* of seven units per acre. The Planner maintains a *happiness* of 9.0 to 10.0 throughout the simulation; the Developer's *happiness* is 9.0 to 10.0 for the first five years until the *housing demand* is met, when redesignation applications are no longer approved. The Citizen's *happiness* is 2.0 to 3.0 throughout the simulation due to the increase in density. This scenario results in the *development potential* being 70% more than the *housing demand* providing for a potential flood in the housing supply.

Figure 31 shows the land-use change over the ten year period based on the business as usual parameter initialization, except for the increase in land-use bylaw density. Again, compared to the BAU scenario, the impact on land use is significantly less, being approximately 205 hectares contained within 14 land parcels, with similar land-use allocation; however essentially the same population is accommodated.

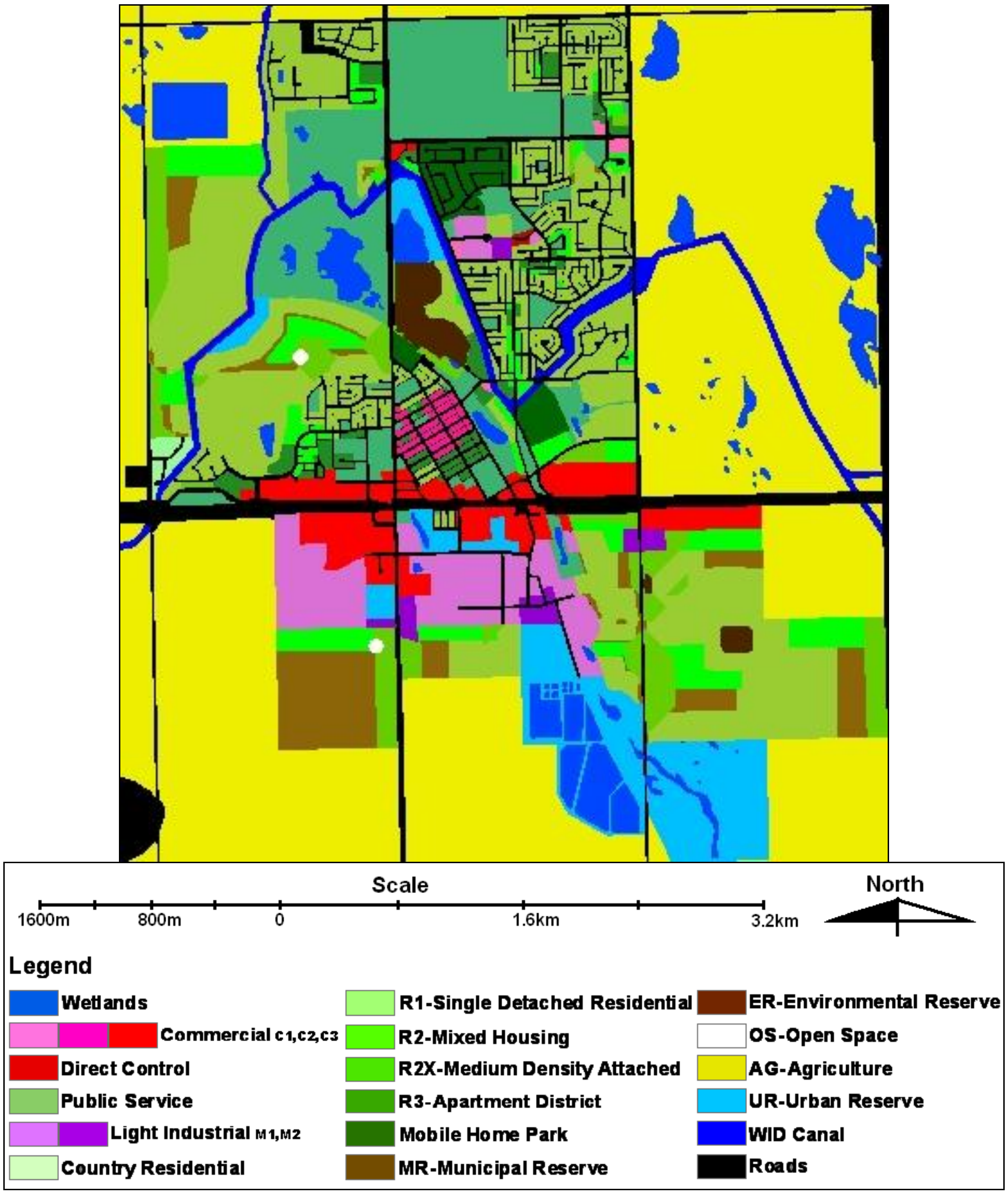

Figure 31: Land-use map obtained with the increase in density scenario

3.2.4 Change in market housing demand scenario

Ewing et al. (2007) predict that the demand for residential housing types is going to change over the next 15 years with the retirement of baby boomers. The demand for larger lot homes is going to decrease as the number of households with children decreases and the demand for smaller lots and attached homes will increase as the number of retired and single-person households' increases. The current demand for large lot homes, small lot homes and attached homes is about 50%, 25%, and 25%, respectively while the predicted demand is about 35%, 30%, and 35%, respectively (Ewing et al. 2007).

In order to accommodate this type of expected future change of community's needs, several key factors will most likely have to be modified including: a new Municipal Development Plan (MDP), revisions to zoning bylaws, and altering public opinion. The creation of a new MDP and the revision of zoning bylaws are straight forward processes for the town planner and council, typically involving inter-departmental consultation, urban and infrastructure planning and limited public consultation. Changing public opinion on the other hand would require a considerable amount of time on the part of the town planner, who will have to educate the citizens on the benefits of planning to accommodate future change in the community. Unfortunately, changing community values and opinions is not typically an easy task.

In the case of the change predicted by Ewing et al. (2007), population distribution will create a change in demand for types of residential housing. Current young families in a community may not be that accepting of a future community of aging and single persons and therefore may not give any heed to planning for such a future, making the planner's job difficult. That being said, the implementation of this scenario in the model is actually quite easy; it involves: modifying the MDP values to allow for more small lots and attached homes and fewer large lot single family homes by increasing the percentages of R2 and R2X and decreasing the percentage of R1 land use; modifying the land-use bylaws to allow for higher density; and modifying the housing type market demand values to match the prediction.

The initialization of this scenario relies on some assumptions: the MDP reflects the expected change in market demand; the planner requires more consistency with the new MDP; the density of the land-use bylaws is increased to seven units per acre; the Citizen has been educated in the changes to the MDP and land-use bylaws as well as the new building fire codes on external walls and relaxes his goal of increasing building setback; the Developer has been educated in the changes to the MDP and land use and therefore changes his goal of increasing density as well as one to one goal for market demand versus MDP; and the bylaws have been changed to accommodate higher density.

With this scenario the Citizen's *happiness* is 6.0 to 8.0 throughout the entire simulation time. Like the business as usual scenario the Planner maintains a *happiness* of 9.0 to 10.0 throughout the simulation; the Developer's *happiness* is 9.0 to 10.0 for the first five years until the *housing demand* is met, when redesignation applications are no longer approved. During the following five years the planner continuously requests revisions, which increases the development time leaving the Developer with no choice but to not submit land-use redesignation applications causing the Developer *happiness* to fall to 2.0 to 3.0. By the end of the simulation the *development potential* is 30% greater than the *housing demand*.

Figure 32 shows the land-use change over the ten year period based on change in market housing demand. Compared to the BAU scenario, the area over which land use has changed is significantly smaller, being approximately 176 hectares contained within 11 land parcels. The percentage of each residential land-use type follows the revised MDP regulations and *Housing type market demand* as expected: 33% R1, 31% R2 and 36% R2X, which is also visible in the land-use map.

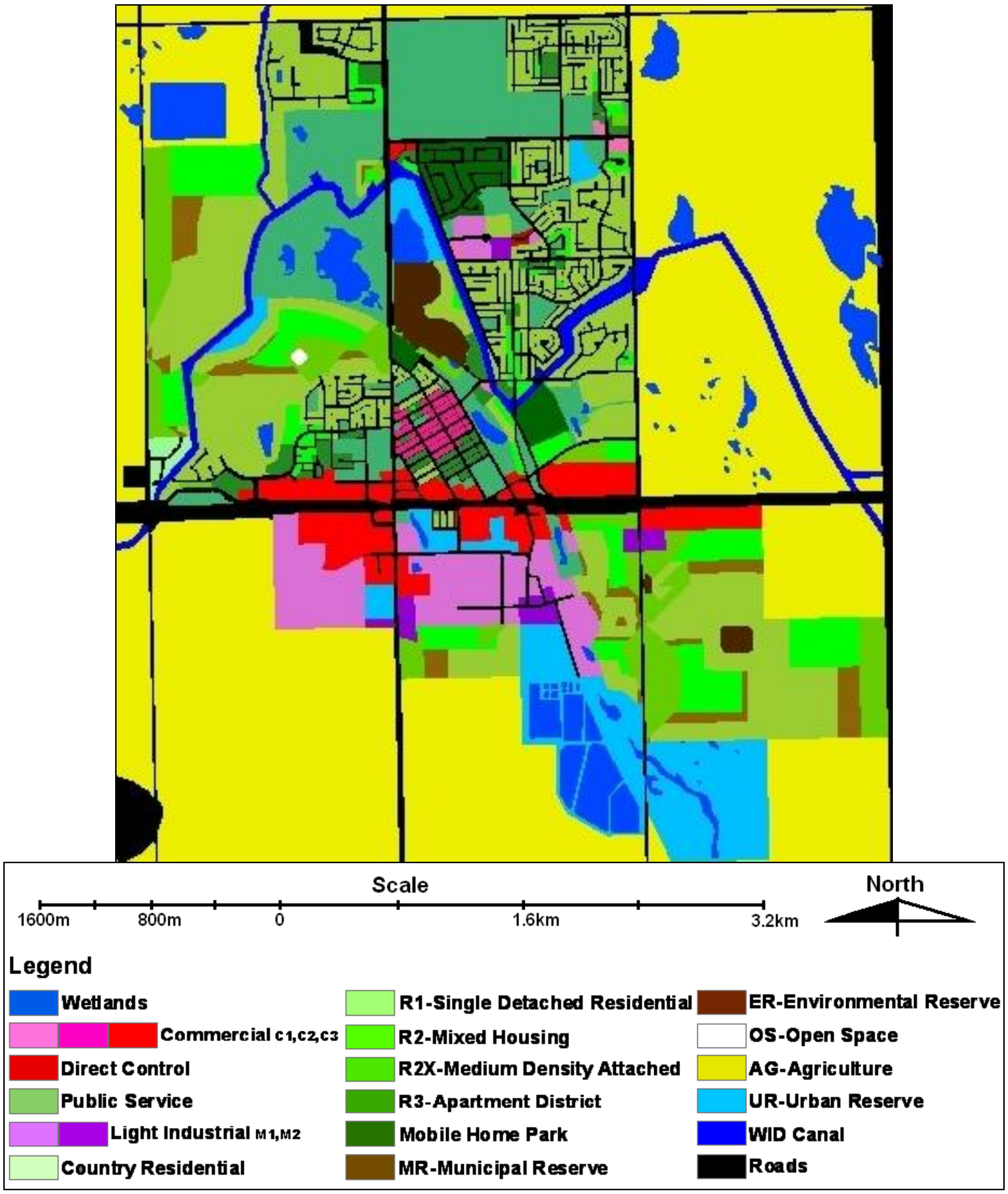

Figure 32: Land-use map obtained with the change in market housing demand scenario

3.2.5 Sustainable development scenario

This simulation is a combination of the “reduction in development approvals per year” scenario and the “change in market housing demand” scenario, but also includes a decrease in the dedication of wide streets from 34% wide (21 m in width) and 66% narrow (15 m in width) streets to 5% wide and 95% narrow streets, and a change of the Developers goal of *Willingness to move wetlands* to no displacement of wetlands.

Throughout this scenario, the *happiness* of all three agent types remains between 7.0 and 10.0. The Planner manages to meet the *housing demand* by year 9, the Developer has his proposed redesignation applications approved, and the Citizen has been educated on the new MDP and is pleased to that see wetlands are not being impacted.

Figure 33 shows the land-use change over the ten year period based on the sustainable development scenario. Compared to the BAU scenario, the area over which land use has changed is significantly smaller, being approximately 198 hectares contained within 11 land parcels, and is only slightly larger than both the “change in market housing demand” and the “reduction in development approvals per year” scenarios. As expected the land-use allocation is similar to the “change in market housing demand” scenario. The change in the Developer goal to not disturb wetlands creates more intricate land-use patterns, presumably a more interesting community; however it possibly creates more complex roads and utility infrastructure.

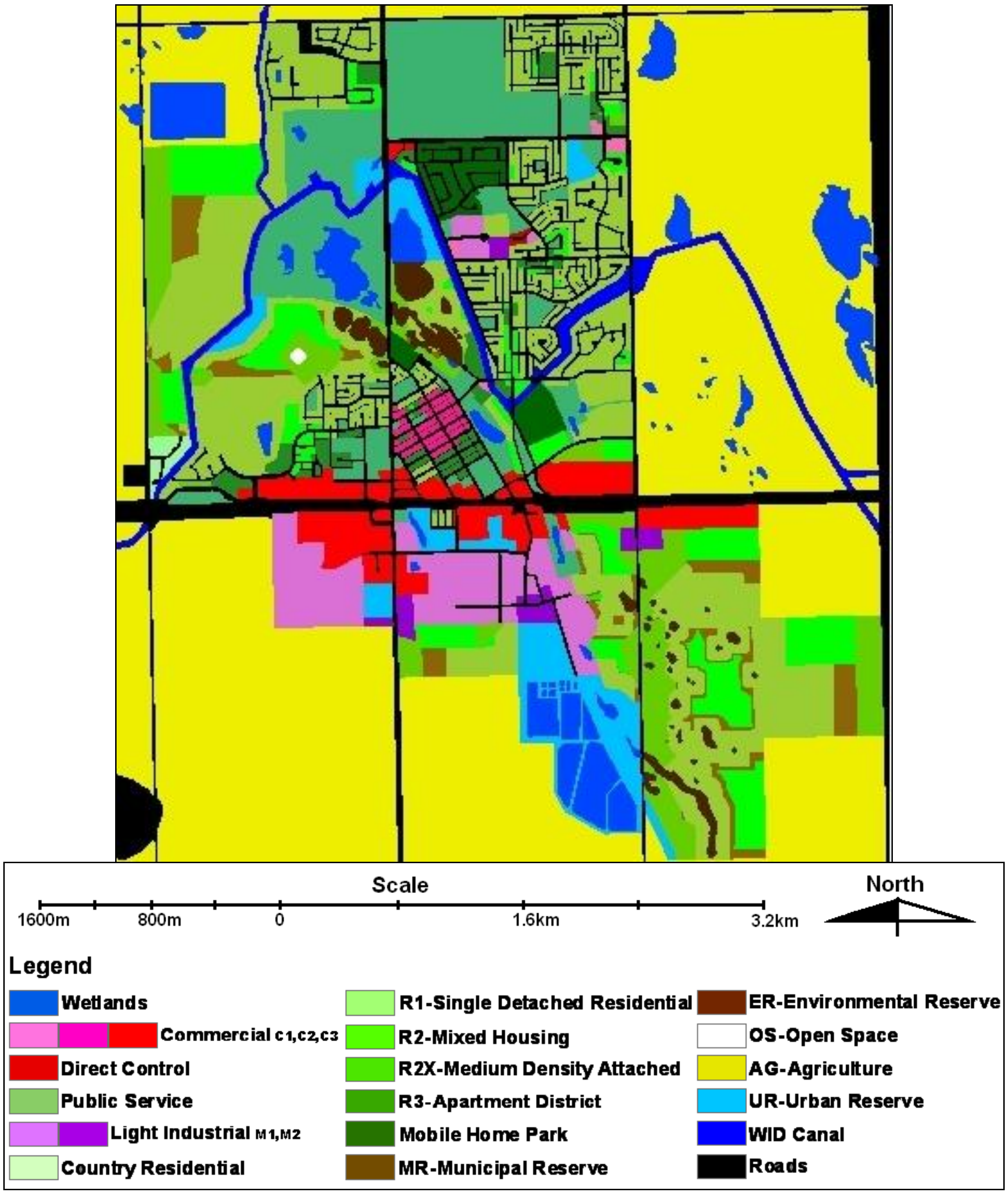

Figure 33: Land-use map obtained with the sustainable development scenario

The different scenarios shown above present the potential for this type of model in simulating the impact of agent goals, government regulations, design standards and market demand on land-use change, land-use patterns and pace of growth.

3.3 Validation of the results

The results of the different scenarios were presented to the Planner of the Town of Strathmore and the Civil Engineer contracted by WestCreek Developments for the Strathbury development, both of whom are considered experts in their field; they were asked to provide comments and criticisms. The persons were selected based on their knowledge, their interest in this research, and their approachability. The following are written comments received from the experts on the model in general and results of the above scenarios (Engineer 2009; Planner 2009):

- "I like the overall concept, and I think this is a great model" and "your model has some interesting elements."
- "You have tried to represent the data quantitatively, but I think this is a huge challenge to nail exactly."
- "Planning is very political and I don't know how you would accurately represent this in your model."
- "This type of a model would work better for a developer and their consultants."
- "The model did show how the various scenarios impacted the consumption of available land. This is a very positive outcome of the model."

- "The model predicted very similar results regardless of the scenario you used. The major exception was the ER/MR which is more obvious based on the selection of options."
- "The model could use work on ER allocation by including environment data (contours, trees, water, etc.), and MR allocation by including community needs (schools, recreation needs, etc.)."
- "The impact of higher density (although you used only a moderately high density) did not show significant differences in single or multi family development. Perhaps because the density used was low or because of the decision process."
- "The municipality really has little say on the decision to build multi-family projects; rather it is the developer who keeps a keen eye on the market and will request this type of zoning when they feel the market is there ($$). The municipality should not (and normally does not) interfere in the market, choosing one development to get an advantage over another by agreeing to multi-family for one and not another."
- "I did not see commercial and industrial allocation on the plans."
- "I feel this tool, as it matures, can be valuable to municipalities as they try to stay ahead of demand and look towards the future."

The feedback offered by the experts provided input on the value and application of the model. It also provided interesting observations on the similarities and differences between the scenarios, as well as a potential problem in land-use allocation and the exclusion of some land-uses. Constructive criticism was also given on the limitation of not including politics in the model, but also the understanding of the complexity of attempting to include politics. The comment regarding the usefulness of the model exclusively for a developer probably originates from the fact that the *land development planning* was approached from the perspective of an engineer, which is discussed in the following chapter, rather than the perspective of an urban planner and as such excludes the politics of the process. The model was also criticized for the misplacement of development control onto the Planner, as development applications approved per year, rather than onto the Developer, as development applications submitted per year.

Chapter Four: Conclusion

This model is among the first attempts to contribute to the field of agent-based modelling in the Geomatics Engineering, Civil Engineering and Land-use Planning disciplines. This research has identified the fundamental parameters relevant to the *land development planning process* through a case study. The process was formalized into a simple agent-based model that accounts for social, economic, regulatory, and environmental factors. The results of the model and the comments provided by the experts show that this model has the potential to provide insight into the impact of municipal planning policies and stakeholders' goals in residential land development planning. This model is a first attempt at designing and implementing a modeling tool that is able to reveal information about the *land development planning process* that would otherwise be difficult to obtain.

4.1 Potential of the model

This research was primarily focused on the decision-making process during the *land development planning process* of the Strathbury residential land development case study. The creation of this model from an engineering aspect gave a very quantitative approach to the interview process and conceptual model development, establishing stakeholder goals as numerical figures, quantifying those factors impacting the decision-making process, and deriving formulas to mimic the decision-making process. The model allows stakeholders to test different goals and policies, providing the opportunity to quickly analyzing possible future impacts before their implementation.

Since social, economic, regulatory, and environmental factors throughout Canada share several similarities, the model developed in this project has the potential to be replicated for use within another small community almost anywhere in Canada with relatively minor modifications to the parameter values. However, adapting the model to different stakeholder goals would require modifications to the computer code.

By proving the value of a simulation model having few stakeholders and a small geographical extent, the model could in the future be enhanced to include a larger number of stakeholders having more complex interactions and expanded to cover a much larger and more complex region. There are many regions in the Province of Alberta and elsewhere that would benefit from such a model.

4.2 Future improvements to the model

As mentioned by one of the experts when validating the model results, residential development cannot exist without the addition of various service sectors. The model therefore needs to be expanded to include other land development in other sectors that co-exist with residential including commercial, industrial and service.

A large number of parameters were used in this model. A sensitivity analysis can identify the parameters that are highly correlated, possibly allowing for the removal of some of them while still achieving comparable results. A sensitivity analysis can also determine the parameters that are the most influential on the system, whereby slight changes in the parameter value give rise to significant changes in the system. Based on the model results, it is believed that density and population are sensitive parameters. Since the willingness to disturb wetlands is a binary parameter, it would also be a sensitive parameter. Future work should include a sensitivity analysis of the model parameters.

The model attempts to simulate the change of behaviour of the stakeholders as the change of goals of the agents in a binary quantitative fashion. The direction of behavioural change is quite often easily derived; however the magnitude of change is not so easy. Determining the level of happiness or unhappiness, or the amount of behavioural change is quite subjective and falls into the realm of “fuzzy logic”. Ligtenberg et al. (2001) state that fuzzy set theory should be explored in agent-based modelling as a way to enhance the decision making for agents. Implementing such techniques would require the expansion of interview questions to ask about past experiences, the decisions that were made and the resulting change in behaviour. The questionnaire could ask what if scenarios posed from different standpoints attempting to get a consistency in answers. Future research in this area should include a research team member from the social sciences to help in capturing human behavioural change. Such a researcher would be able to help in developing a proper questionnaire to accurately capture human behavioural change, as well as engaging with stakeholders thereby increasing the participant base.

This research overlooked the “NIMBY” (Not In My Back Yard) apprehension as a behaviour of the citizen agent. In the real world, although it is not required by the developer, communities are quite often pleased when a developer requests their opinions regarding the development proposal in a voluntary pre-application meeting. They are often displeased and alarmed when they are not included only to receive the formal application and typically voicing disapproval during the public hearing. I hypothesize that NIMBY is a contributor to urban sprawl. Since residents of an established community have not dealt with construction and disturbance for many years, their community has most likely developed an identity and values, they may have developed a bond with their “backyard”, and they have most likely established community organizations. A proposal to develop adjacent lands would create disturbance during construction, create additional traffic upon completion, and it may not fit their identity or values. Established communities will most likely oppose the proposed development and organize to defend “their backyard”. This may cause developers to choose not to propose a development adjacent to an existing community having a large opposition, but rather choose land that is further away that is the “backyard” of only a few land owners driving the “urban sprawl” machine. Residents in a new community are already dealing with the construction and disturbance within their own community; their community perhaps has not developed an identity or community values, they may not have a bond or with their “backyard”, and neighbourhood organizations have not been established. A proposal to develop lands adjacent to a new community creates little additional inconvenience; the residents have little bond with their adjacent lands, and they are not organized to defend their community. New communities will most likely give little consideration to the impact of new adjacent developments on their community; this lack of opposition may also be a contributor to the “urban sprawl” machine. The “NIMBY” apprehension could have been implemented as a function of the number of existing homes directly adjacent to the proposed development.

There are improvements that should be made to the model including: the shift of development control from the Planner to the Developer, acquiring actual property market value data, and updating the Municipal Development Plan (MDP). Other additions that would increase the value of the model include:

- Changing housing market value based on supply and demand;
- Adding a landowner agent to make decisions regarding the sale of their land;
- Creating a module that varies property value based on the adjacent land-use;
- Having environmental factors (topography, vegetation, and habitat) in the allocation of land use.
- Adding a utility company agent and utility infrastructure data impacting land-use change patterns; and
- Creating a dynamic Municipal Development Plan that can slowly implement the long term goals of the planning authority including major transportation corridors.

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Appendices

Appendix 1: Questionnaire provided to representatives of stakeholder groups

Developer representative

1. Can you give me an overall idea of what the goals of your organization are regarding land development?
2. What were your initial goals when you starting planning the Strathbury land development project?
3. What density of development were you hoping to achieve for these lands?
4. Can you quantify your proposed development based on the percentage of land you allocated as the different land-use types (R1, R2, R3, C, MR)?
5. Did you believe there were any physical or regulatory constraints hindering the proposed development, if "yes" what were they?
6. Did you believe there were any areas within the proposed land development that should be protected?
7. Did you believe there were any environmental constraints such as wetlands within the proposed development, if "yes" were you willing to move the wetland to improve your development layout?
8. Did you have an informal meeting with the Community before submitting your Land-Use Redesignation application to the Town?
9. What was the opinion of the Community to your proposed development and did the Community give you any comments?
10. Did you make any changes to your development proposal based on the comments from the Community?
11. What were those changes and can you quantify your changes as in question 3?
12. Did you have an informal meeting with the Town before submitting your Land-Use Redesignation application to the Town?
13. What was the opinion of the Town to your proposed development and did the Town give you any comments?
14. Did you make any changes to your development proposal based on the comments from the Town?
15. What were those changes and can you quantify your changes as in question 3?
16. Following the submission of your Land-Use Redesignation to the Town did the Town inform you of their intentions regarding the acceptance or refusal of your application based on comments from the Community?
17. Did you make any changes to your development proposal based on the Towns intentions?
18. What were those changes and can you quantify your changes as in question 3?
19. Are you happy with the results of the Land-Use Redesignation process?

20. Is there anything you would like to change about the process?
21. Is there anything you would like to change about the proposed land development?

Planner representative

1. Can you give me an overall idea of what the goals of your organization are regarding the growth of the Town of Strathmore?
2. Based on your development plans for the Town what was your initial goal for those lands within the Strathbury land development project?
3. What density of development were you hoping to achieve for these lands?
4. Can you quantify your proposed development based on the percentage of land you allocated as the different land-use types (R1, R2, R3, C, MR)?
5. Are there any areas within the proposed development that needed to be protected?
6. Based on the Town's Wetland Policies are there were any wetlands within the development?
7. What is the multiplier by which you need to increase the area for wetlands should the Developer wish to move them?
8. Did you have an informal meeting with the Developer prior to the submission of the Land-Use Redesignation application?
9. What was your opinion of the proposed development and did you recommend any changes to the Developer?
10. What were those recommended changes and can you quantify your changes as in question 3?
11. What was our opinion of the proposed development submitted in the Land-Use Redesignation by the Developer?
12. Can you quantify your opinion as in question 3?
13. What was the opinion of the Community to your proposed development and did the Community give you any comments?
14. What were those recommended changes and can you quantify the changes as in question 3?
15. Did you make any changes to your opinion based on the recommended changes of the Community?
16. Can you quantify your changed opinion as in question 3?
17. Are you happy with the results of the Land-Use Redesignation process?
18. Is there anything you would like to change about the process?
19. Is there anything you would like to change about the proposed land development