Great Lakes
Regional Water Conflict Analyses

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

This research proposes a holistic framework to help understand and mitigate the interrelated and successive conflicts that occur over water resources in the Great Lakes and the rivers flowing into them. Local Canadian governments, in addition to many public and private companies, are heavy water consumers, who extract vast amounts of water from water sources such as the Great Lakes. Moreover, temperature changes, and increasing storm water in the past few decades, added to pollutants such as phosphorous pouring into the Great Lakes from various origins, place more pressure on these valuable, yet vulnerable water sources. Various NGOs and the states and provinces surrounding the Great Lakes strive to protect the Great Lakes from excessive water extractions and pollutants. The different priorities of the aforementioned stakeholders have become sources of various disputes.

Traditional conflict resolution publications tend to focus on investigating each of the conflicts independently from the other disputes existing among the stakeholders. However, a holistic view is required to understand the conflicts, acknowledging the previous disputes, which have transpired in the past when analyzing each conflict. This broader perspective approach presents a better ability to study potential future conflicts, since it enhances the predictability of the scenarios, which might occur later during other disputes.

In the first step, after identifying the relevant stakeholders associated with the Great Lakes, conflicts among them are analyzed using the Graph Model for Conflict Resolution (GMCR) approach. However, the input for each conflict's GMCR model is highly influenced by the previous conflicts' outputs. Modeling and analyzing this influence are accomplished through intricately assessing the results of the previous conflicts' GMCRs and linking them to the gathered information on the current conflict of interest.

In the next step, major external variables that affect the current steady-state system are investigated. Political happenings, economic factors, social trends, technological advances, legal changes, and environmental crises are some of the key variables that are investigated. Then, several scenarios based on this external analysis of the system are proposed and utilized for enhancing future decision-making.

The aforementioned steps are showcased using three case studies of disputes among the Great Lakes stakeholders. The main studied case is the Lake Erie pollution conflict which is investigated in two instances of 1970s and 2010s. It is concluded in this thesis that if the 1970s dispute had been investigated using the causal loops, GMCR, external analysis, and scenario analysis, the stakeholders, especially local authorities in the Lake Erie watershed, would have been able to make better decisions in the more recent dispute in 2010s.

This research with the current holistic framework should also enhance understanding of the interrelated conflicts over essential topics such as financial, health, and environmental concerns caused by pollution (specifically algae blooms) in the Great Lakes and the rivers flowing into them. The developed understanding, in addition to the results of the conducted external analysis, should help decisionmakers, especially water utility providers, who carry a huge responsibility towards millions of water users, predict and prevent potential water disputes with other stakeholders. Although the case studies in this research focus on the Great Lakes and their stakeholders, the proposed framework is applicable in other contexts as well.

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This thesis is the result of trust, support, effort, and initiative of many. Without their help, the completion of this project would not have been possible.

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I would like to thank my loved ones; my precious parents Dr. Gholamhassan Payganeh and Mrs. Azar Azizi Shalbaf for all their warmth and care, and my beloved husband, Dr. MirHossein TabatabaeiLotfi, who have supported me throughout the entire process by keeping me content and helping me to remain focused on my work. Also, I am truly thankful to my little dearest, Elias for keeping me strong. I will be grateful forever for their love.

Dedication

To the dearest of my life, my loving husband, MirHossein

Thank you for your love, encouragement,
patience, and endless sacrifices throughout my academic career. This thesis and the pursuit of my goals would not have been possible without you.

And Elias

With the same age as my PhD program
You are the one who gave me the strength to keep going step by step
Accompanying me with your own little steps.

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

1.1. Background and Motivation

The North American Great Lakes (mentioned as Great Lakes hereinafter) are critical to Canada and the US as they are a drinking water source for more than 33 million Canadians (from eight of Canada's 20 largest cities) and Americans (Mehta 2016). However, various threats such as increased local population in the Great Lakes watersheds leading to more local water usage (Matheny 2017), toxins, invasive species, and other pollution accumulating in the Great Lakes (e.g. 22 million pounds of plastic garbage each year) (Zukowski 2016), and also climate change which is warming the waters (NOAA 2016), threaten this world's largest source of surface freshwater. Another threat is the need for water extraction from the Great Lakes to US and Canadian cities outside of the Great Lakes watershed. For example, the city of Waukesha in Wisconsin has fought hard to pipe water from Lake Michigan, due to its currently radium contaminated water wells (Mehta 2016). Also, the increased water demand in other parts of the world other than the US and Canada which imposes pressures on Canada and US to export water from this freshwater source, is yet another threat affecting the Great Lakes from a global perspective.

These threats have been a major incentive for funding such as the Great Lakes Restoration Initiative (GLRI) (Great Lakes Restoration Initiative, 2020) and joint initiatives such as the Great Lakes - St. Lawrence River Basin Sustainable Water Resources Agreement (a pact bringing together eight states from the US, and two Canadian provinces adjoining the Great Lakes and St. Lawrence River, signed on 13th of December, 2005) (Great Lakes and St. Lawrence Governors and Premiers, 2005). These supportive initiatives have contributed to protecting the Great Lakes from the damaging effects of external threats (Saeger, 2007).

All of these factors (i.e. threats on one side and supporting initiatives on the other), and the associated conflicts among the stakeholders who have a stake in the Great Lakes, have together formed a complex dynamic system which should be investigated through a holistic perspective. In this research, a broader framework for investigating this complex system is developed.

Moreover, with the management of natural resources being a provincial responsibility (Section 92A of the Constitution Act), and the Canadian federal government having authority over topics such as trade, commerce, and inland fisheries, municipalities including local utility managers have been put in a fragile position regarding the ability to deal with concerns and conflicts regarding their water supply systems (Ronan, 2016). This brings about a knowledge gap which needs to be filled; to provide clearer perspectives to these local authorities for better handling of water management conflicts.

This thesis attempts to answer the following research questions:

- What are the main water related conflicts surrounding the Great Lakes?
- Which decisionmakers are involved in the conflicts associated with the Great Lakes?
- What are the current situations of each of these stakeholders? (Note: the word “stakeholders” is used interchangeably with “decisionmakers” and refers to individuals or institutions who affect, or are affected by, the Great Lakes).
- How do these stakeholders interact in the real world? Or, in other words, why are they in conflict with each other?

- How could we help resolve the multiple conflicts among these stakeholders in a systematic and sustainable way? And, which method(s) can contribute to achieving this?
- How can studying previous conflicts among the stakeholders help in understanding the current and potential future conflicts among them? Through which approach can this be done?
- How do external factors affect the current states of each of the stakeholders and also, the existing disputes among them?
- How do each of the stakeholders, especially local municipalities including Cities and Regional Municipalities, and also the Great Lakes as a valuable water resource, benefit from such a research?

1.2. Research Goal and Objectives

The main goal of the current study is to propose a framework for thoroughly studying complex water resource conflicts associated with the Great Lakes watershed. This necessitates some objectives to be met:

1- Investigating existing conflicts in the states, provinces, regions, and cities, surrounding the Great Lakes.

2- Identifying the involved decisionmakers in the conflicts related to the Great Lakes.

3- Studying these stakeholders' preferences in the different ongoing conflicts.

4- Developing a set of options for each of these stakeholders based on primary and secondary data collected throughout the research.

5- Analyzing different possible outcomes of the interactions among the stakeholders using the Graph Model for Conflict Resolution (GMCR) method (Fang, Hipel, & Kilgour, 1993; Kilgour, Hipel, and Fang, 1987). These analyses should consider studying the various conflicts among the stakeholders as a whole, instead of investigating them independent from each other.

6- Shedding light on the external variables, which are not controllable by the stakeholders. These external factors hugely affect the status and potential conflicts among the decisionmakers.

7- Outline different scenarios developed based on the occurrence of shocks related to the external variables.

1.3. Research Methodology

This thesis includes four phases. The first phase (Chapters 1 and 2) focuses on identifying and clarifying the problem at hand and the previously mentioned research questions. The literature on the Great Lakes water conflicts is discussed in depth, outlining some of the conflicts currently affecting the stakeholders. It is also in this section that the knowledge gap is identified. This is crucial to the research since it brings all there is to bear on the complex situation of interest.

In the second phase (Chapter 3), methodologies to model and analyze the current thesis data are investigated. These methods include the Causal Loop step of the System Dynamics approach, Graph Model for Conflict Resolution (GMCR), External Analysis, and Scenario Analysis. The Causal Loops approach provides an initial broad perspective into the dynamics of each of the conflicts. The GMCR approach is used to delve deeper into the stakeholders' status, preferences, and also the relationships among involved decisionmakers. External Analysis investigates the environment in which the conflict is taking place in. This step, added to Scenario Analysis, helps to study different possible outcomes of the conflict in the future. This is to aid in enhanced decision making for the stakeholders of the conflicts.

The information gathering in the first and second phases happened through primary and secondary data collection from various sources. In the primary data collection, various individuals were interviewed to gather different perspectives on the stakeholders' views and the ongoing conflicts among them. The details of the interview processes are discussed in the upcoming sections. Secondary data collection was conducted through reviewing hundreds of articles, journal papers, governmental and private websites, and news sources.

The third phase focuses on using the previously discussed methods to categorize independent and interrelated conflicts and, to develop insights and solutions for those disputes. Three case studies are selected and investigated through the methodologies discussed in Phase II. Validation involves stability and sensitivity analyses as well as functional demonstration and stakeholder evaluation. And finally, the fourth phase of the research is a broad overview of the contributions, proposed future studies, and limitations of the research.

Although the focus of this thesis is on the Great Lakes and the states, provinces, regions, and cities surrounding them, it attempts to develop a broader framework for systematically investigating water related conflicts. In other words, the cases studied in different sections of the thesis, are all linked to the Great Lakes, however, the procedures and methodology used, can be implemented in other geographical contexts and disputes other than Great Lakes conflicts as well.

1.4. Structure of the Thesis

After the current introduction chapter (Chapter 1), in Chapter 2, a literature review on the Great Lakes and its stakeholders and major conflicts is provided. It is in this chapter that the different conflicts surrounding the Great Lakes are discussed. Moreover, the knowledge gap to be filled through this research is also outlined. Then, in Chapter 3, the methodology of analyzing the conflicts is discussed. The results of investigating the chosen cases through system dynamics causal loops and GMCR are described in Chapter 4. Chapter 5 covers a case using causal loops, GMCR, external analysis, and scenario analysis to showcase the proposed perspective in this thesis. And finally, Chapter 6, focuses on the conclusions of the research and the discussions regarding the conflict. Limitations and future research is also discussed in this final chapter. The different phases and steps of the project are depicted in Figure 1.1.

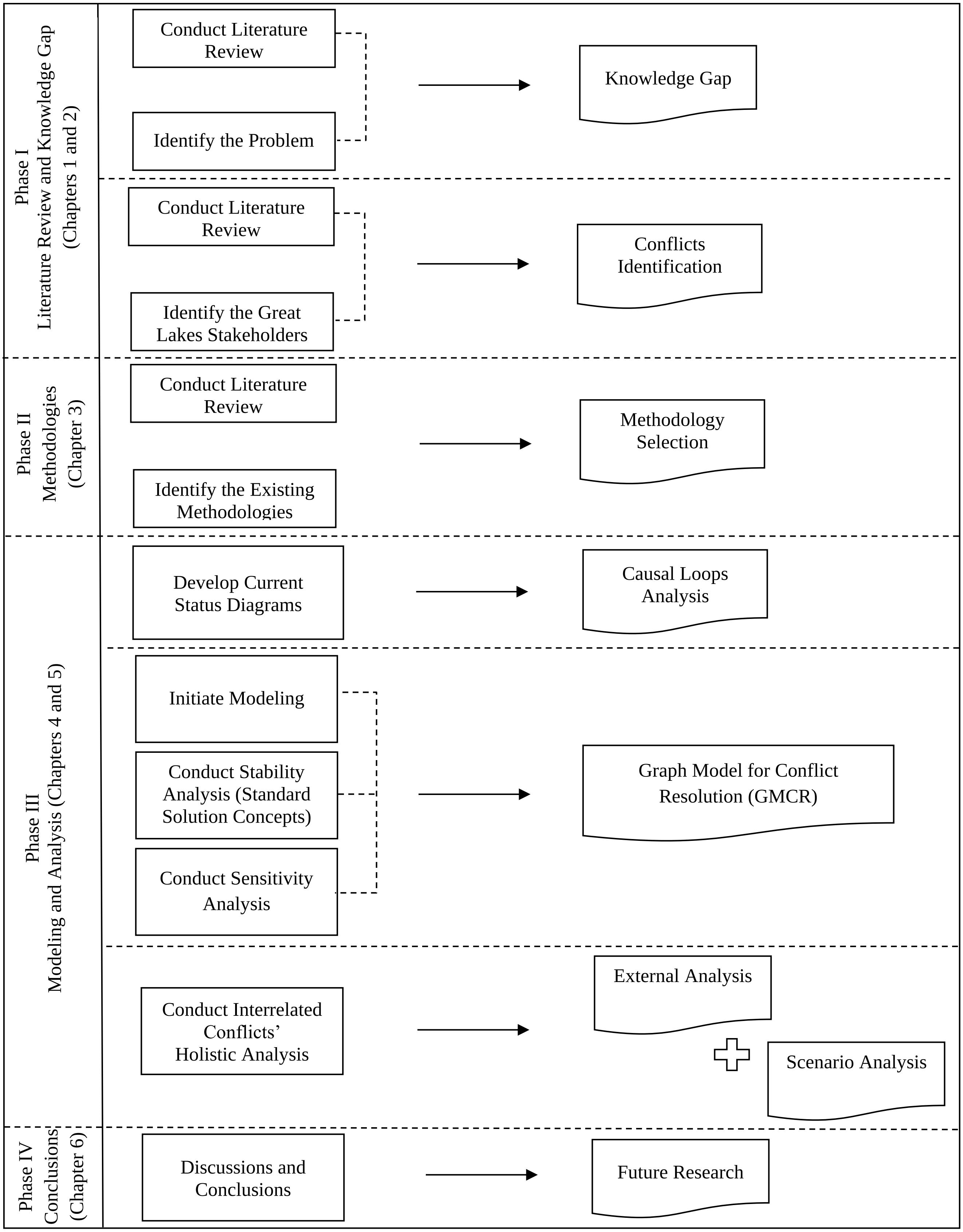

Figure 1.1: Structure of the Thesis

Chapter 2 Literature Review

2.1. Global Water Crises

More than 2.2 billion people throughout the globe, lack access to safely managed drinking water (WHO/UNICEF, 2019). This not only affects their physical health, but also indirectly influences their mental health, education levels, employment, and other aspects of their lives (Vidal, Harrington & Fisher, 2014). For example, in many developing nations women have to walk long distances to reach water, and this prevents them from spending time on school or work (Molle and Mollinga, 2003). Drinking water scarcity puts people in a poverty cycle, making it difficult for them to care for other important aspects of life (GWTF, 2006). These destructive cycles negatively affect people, and in turn, their families, their villages, and their countries as a whole (Molle and Mollinga, 2003).

People are dependent on water sources for their basic drinking needs. Water access is also a necessity for agricultural, manufacturing, industrial growth, power generation (through water dams), job creation, and overall economic development (EU, 2019).

About 260 rivers are currently flowing through more than one country around the globe. And the water in these rivers, must be shared among millions of people (Postel, 2000). Thus, each of these shared rivers is a potential ground for instability or dispute among different decisionmakers (Petersen-Perlman, Veilleux, & Wolf, 2017). Therefore, effective shared water resources management requires creative approaches to ensure win-win resolutions among various involved decisionmakers (Postel, 2000).

2.2. Great Lakes

The Great Lakes are among the internationally shared rivers and lakes in the world. Unique aspects make this shared water resource interesting and challenging to investigate. Firstly, 20% of the globe's fresh water exists in these lakes. This brings in various opportunities for the neighboring provinces and cities, yet presents its own challenges as well (Becker and Easter, 1999). One of the unique challenges would be the increasing interest in other water-depleted nations to access the Great Lakes (e.g. through importing water from Canada or US).

Secondly, the Great Lakes are surrounded by two of the most powerful and influential countries in the world, the US and Canada (Becker and Easter, 1999). Therefore, the actions that these two countries take would be considered intricately by other countries around the world. The approach these governments or related decisionmakers seek to solve their conflicts might turn into action models for others, and thus, it is necessary to act as wisely as possible to avoid major global conflicts as well. Standardized conflict resolution frameworks can be developed by these influential countries to guide the resolving of similar conflicts worldwide.

The third unique aspect of the Great Lakes is that they are surrounded by eight states from the US, two Canadian Provinces, tens of municipalities, commercial companies, and environmental NGOs, and millions of people (Dagenais and Cruikshank, 2016). This high number of decision-making authorities and other types of influential decisionmakers substantially increase controversial preferences and thus, disputes regarding topics related to the Great Lakes (Figure 2.1 depicts a map of the Great Lakes surrounded by states from the US, Canadian provinces, and their relative share of the Great Lakes).

Figure 2-1: The Great Lakes and the Surrounding States and Provinces (Wikimedia Commons, 2018)

All of these unique aspects regarding the Great Lakes necessitate a thorough understanding of this valuable water resource. To develop such an understanding, the first step is to study the governmental institutions, companies, and other decisionmakers associated with the Great Lakes. This ensures that we understand their preferences and stakes in the Great Lakes, which in turn, helps us better analyze their associated conflicts.

2.3. The Great Lakes Stakeholders

2.3.1. Residents of Great Lakes Watersheds

Residents of Great Lakes watersheds in general are the initial stakeholders of the Great Lakes since they are directly affecting and being affected by the Great Lakes. Residents are dependent on the Great Lakes, which are providing them with fresh drinking water, in addition to their water supply for other uses. Moreover, any water saving initiative, or search and development of other water sources infrastructure, would also benefit or harm this important stakeholder (Environment and Climate Change Canada, 2017).

2.3.2 Canadian and US Federal, and Provincial and State-wide Governments

Canadian and US Federal governments, in addition to the Great Lakes' neighboring Provincial and State-wide governments are major stakeholders regarding the Great Lakes. Their responsibility towards maintaining the Great Lakes, substantially increases their involvement with the Great Lakes' water management initiatives (Environment and Climate Change Canada, 2017). They have power over regulating water extraction, treatment of waters entering and exiting the Great Lakes, or other activities that affect these major water sources in any way. One of the other influences they have is the money they can allocate towards the Great Lakes' restoration. Overall, they are considered extremely influential stakeholders with high bargaining power because of their authority over regulations and budgets.

2.3.3. Cities, and Regions Surrounding the Great Lakes

Cities and Regions are in an interesting situation since they have some authority over policy making at the local level and also have limited budget allocation. However, they also have responsibilities over the implementation of policies (sewage or drinking water treatment standards) set by higher regulating authorities such as provincial or federal level governments. Moreover, they are responsible for interacting with each other as well, since many of the Provincial or even local initiatives, require multiple cities to cooperate closely to implement projects (anonymous interviewee #4, personal communication, 2020). This complicates the Cities and Regions' role in preserving of the Great Lakes as it brings them some power, but at the same time, they must answer to higher authorities and other municipalities regarding their responsibilities on conducting initiatives (Ronan, 2016).

The more complex cases are the Cities or Regions which are in the Great Lakes watershed, but at the same time, are not a riparian zone to the Great Lakes. For example, Waterloo, a Southern Ontario city, is in Lake Erie's watershed, however, it is landlocked, and it supplies its water needs from groundwater and Grand River (which flows into Lake Erie after passing through the City of Waterloo). This hugely increases the authorities' anxiety to sufficiently provide water for the growing population of the City (anonymous interviewee #1, personal communication, 2020).

2.3.4. Agricultural Water Users

With climate change, agricultural practices are being placed under the spotlight by different decisionmakers (e.g. NGOs, community activists, and governments) to become more effective in decreasing the amount of water used, and also in lessening their negative effects on polluting the Great Lakes.

Agricultural water use is one of the major consumers of water resources. For example, agricultural water usage accounted for about 20% of the total daily water consumption in Ontario in 2001 (De Loë, Kreutzwiser, & Ive 2001). Much of the agricultural water usage in Ontario occurs in Southern Ontario for livestock watering, fruits and vegetables growing, and also irrigation. Since water demand is already very high in Southern Ontario and also since agricultural water usages, especially the irrigation sub-category, are usually seasonal, it is important to understand how these water drawings affect or impose pressures on the Great Lakes in different times of the year. Another major concern with these stakeholders is their use of fertilizers which hugely contributes to increased levels of phosphorous in the Great Lakes, which in turn increases algal blooms (Shin, 2013). Negative effects of algal blooms are discussed further in Chapter 5, Section 5.1.

Variables such as climate change effects in recent years, which might change governmental regulations on water usage and agricultural fertilizer application, would most probably change this stakeholder's status quo.

2.3.5. Manufacturing Industries

Surface freshwater resources such as rivers and lakes have been directly providing about 75% of the water used in manufacturing industries in Canada. Another 14% is supplied from utilities associated with public municipalities which also originally source their supplies from freshwater resources (Statistics Canada, 2009). In Canada's manufacturing industries, most of the water usage is by paper manufacturing companies (46%), followed by metal industries (about 35%). Most of this freshwater usage by manufacturing industries has been occurring in Ontario (about 45%) followed by Quebec (about 24%) and British Columbia (about 17%). Some of this water is discharged (about 3500 million cubic meters per year), and most of it (about 75%) is returned back into freshwater sources. However, more than 38% of the discharged water is not treated in any capacity, before flowing back into surface freshwater bodies (Statistics Canada, 2009).

2.3.6. Water Bottling Companies

The bottled water business has been expanding over the recent years. The industry was valued at 185 billion USD in 2015, and is expected to grow to 334 billion USD by 2023 (Market Reports World, 2020). This business growth has sounded alarms for many stakeholders, introducing a potentially major conflict among the many decisionmakers in the water management field. Signs of this upcoming conflict can be traced in the daily news in more recent years. For example, Nestle is pumping water from aquifers that feed Lake Michigan (in Mecosta County) (Goodman, 2017) or is attempting to get into a long-term contract with the Ontario Provincial Government to buy a 110-meter deep well near the City of Guelph, Ontario, raised many speculations regarding the future of the Great Lakes and Southern Ontario's drinking water sources.

2.3.7. Fisheries

Fisheries are one of the other stakeholders which are vulnerable to changes in the Great Lakes status. High levels of water usage by the other stakeholders, less sewage water treatment, more agricultural water runoffs, in addition to higher temperatures imposed by climate change effects, are all variables which put more pressure on the Great Lake's system, which in turn, negatively affect fisheries' businesses (Shin, 2013). Fisheries are usually strong supporters of imposing strict standards on water treatment, water usage, agricultural fertilizer application, or other limiting rules and regulations.

2.3.8. NGOs

NGOs are other stakeholders which affect and are affected by the Great Lakes. Some of these NGOs provide grants, share information, and offer training and consulting to businesses and other stakeholders of the Great Lakes (e.g. Freshwater Future Canada (2020) and Alliance for the Great Lakes (2020)). Some of these NGOs receive funding from governments and communities to run initiatives or programs to save more water (Government of Canada, 2015).

Some other NGOs contribute to Great Lakes conservation through focusing on ensuring full implementation of local and international governmental acts and agreements relevant to the Great Lakes. An example includes the Great Lakes Protection Act Alliance (2020) which monitors and encourages government progress towards implementation of the Ontario's Great Lakes Protection Act (Government of Canada, 2015).

2.3.9. Developers and Contractors

The other group of Great Lakes stakeholders affecting the dynamics of the water management system, are developers and contractors. Almost all water and wastewater infrastructure construction and maintenance projects, which should be approved by municipalities and other government bodies, are conducted by this group of stakeholders. Although a minimum quality and budget is usually assumed by the governmental bodies for implementing the projects, in many instances, the work done by the contractors sets the standard for governmental infrastructure budget approvals (anonymous interviewee #4, personal communication, 2020). Therefore, the contractors' and developers' decisions and actions play huge roles not only in required water and wastewater project budgets, but also in the quality of the conducted projects.

2.4. The Great Lakes Conflicts

2.4.1. Pollution of the Great Lakes

The Great Lakes are a source of water for many commercial decisionmakers, and drinking water for millions of people and thus, the health of the Great Lakes is critical to many. However, population growth, climate change, revitalization in farming experiences, and many other variables have all contributed to a serious rise of different pollutants in the Great Lakes. In addition to point source and non-point source pollutants which affect the Great Lakes directly, rivers flowing into the Great Lakes are also a major source of pollution which have been focused on more recently regarding their effects on the quality of the Great Lakes' waters. Phosphorous levels, and more recently, pollutants such as artificial sweeteners, have considerably increased in the Great Lakes (Government of Canada, 2018). It has been shown in a study from 2013 that Lake Erie was filled with about 72 metric tons of artificial sweeteners in 2013 (Spoelstra, Schiff & Brown, 2013). Lake Erie's phosphorous levels were estimated to be 11,476 metric tons in 2018 (Environment and Climate Change Canada, 2020).

Many stakeholders play direct or indirect roles in increasing or decreasing pollutant levels in the Great Lakes. Agricultural and livestock farmers and industrial manufacturers are main contributors to increased phosphorous levels in the Great Lakes. However, governments (at all levels) are main contributors to phosphorous decreasing initiatives which aim to reduce the negative effects of pollutants in the Great Lakes (Government of Canada, 2018). Although, local governments such as municipalities are in charge of maintaining sewage systems and thus, are responsible for the phosphorous that flow into the Great Lakes from cities' sewage systems. But again, these local governments are vulnerable to the negative consequences of high phosphorous levels in the Great Lakes. For example, algal blooms which are a consequence of high phosphorous levels, could clog intake pipes which are used for drinking water and other uses (Shin, 2013; TidesCanada, 2015).

As discussed above, many stakeholders are involved with the Great Lakes' pollution levels. Although some contribute to a higher quality water supply through investments and increased regulations, some other stakeholders, through the nature of their business or activities, increase pollutant levels in the Great Lakes. And some other, such as municipalities, have both positive and negative effects. All of these issues complicate the conflict.

2.4.2. Conflicts between Regional Governments and Local Municipalities

In some of the Great Lakes watersheds, Regional governments are responsible for finding, maintaining and treating water sources for their regions. However, local municipalities in these regions deliver the retail water to final customers. They also have the responsibility of returning the used water to regional governments for treatment (Region of Waterloo, 2020a). Therefore, there is less incentive for these local municipalities to actively take part in water conservation initiatives, since they are not directly responsible for finding alternative water sources. And also that they do not have to spend more money if more water has been used, since treatment plants are owned and operated by the regional governments (anonymous interviewee #3, personal communication, 2020). Moreover, these local municipalities sell the water to the customers, generating revenues for their operations, and structure. This means that if they sell less, at the end of the day, they are making less money. This is yet another reason why they might not be so eager to take part in water efficiency programs, run by these Regional governments (anonymous interviewee #2, personal communication, 2020).

The other concern is that water consumption metered data is either not error-free, not sent to the Regions in time, or not collected at the local municipalities' level at all. The complexity of the billing system has also been mentioned as another issue, which makes understanding and analyzing the bills harder by the Regional Governments.

Moreover, in some regions, water is sold to the local municipalities, at a lower price than the water sold to the final customers. For example, the Region of Waterloo sells water at a price of $1.0953 per cubic metre to the City of Waterloo, and the City, sells the water with a higher rate of $1.97 per cubic metre to the final users (The City of Waterloo, 2020; Region of Waterloo, 2020b). Although this price increase is mostly for the City to cover its distribution and billing costs, the amount of the price increase might raise a conflict between the two.

Also, since the local municipalities are separate entities working with consumers, the Region might not have permission from the other entities to freely use the gathered water data, and this results in less clarity when analyzing and making decisions.

Several other communications issues have also been happening which could result in conflicts between the Region and local municipalities. These communication issues have been occurring in instances of emergency, such as watermain breaks caused by construction projects (anonymous interviewee #5, personal communication, 2020).

2.4.3. Conflicts among Neighboring Municipalities

Water fights involving different cities surrounding the Great Lakes is one of the other seemingly unavoidable Great Lakes' conflicts. For example, Waukesha, Wisconsin was faced with a shortage of fresh water in 2014 due to its own water sources being "contaminated with high levels of naturally occurring cancer-causing radium" (Mehta 2016). The Waukesha City asked for permission from the eight states surrounding the Great Lakes to pipe water from Lake Michigan as an alternate source of water. However, the City was faced with fierce opposition from many, including the Mayor of Thunder Bay, who was concerned about the Great Lake's vulnerable situation. This issue has yet to be resolved and is discussed in more detail in Section 4.1.5. This is one example of the many foreseeable conflicts which will most likely arise in the near future among states and cities surrounding the Great Lakes. The anxieties among these cities concerning their diminishing water supplies are understandable and thus, any conflict resolution initiative has to take into consideration all their fears and panic over the water shortage concern.

Another ongoing conflict among the municipalities is seemingly, them not willing to share data and information with each other. These neighboring authorities cooperate in a lot of water projects and are either recipients or providers of services to each other. This requires them to communicate frequently, through high quality channels such as more face to face meetings. However, this is not always the case. Cooperating on many projects translates in sharing limited resources. Thus, these neighboring municipalities feel worried to share all their information, in fear of leaking valuable data, which might make them vulnerable to their competitors in accessing water sources (anonymous interviewee #5, personal communication, 2020).

2.4.4. Conflicts between Municipalities and Developers/Contractors

Municipalities outsource their construction projects to developers, who cooperate with the municipalities through agreements. However, based on one of the interviews conducted during this research, it seems that these projects are not always properly conducted or inspected before being used. For example, "the pipes going underground might not be sealed properly to begin with. The connections are bad, or the way the backfills are done on the construction leads to basically cracked pipes or leaking pipes that then immediately start leaking just as much as old infrastructure, if not more" (anonymous interviewee #3, personal communication, 2020).

2.4.5. Conflicts between Governments and Businesses

Another major conflict which is affecting most of the aforementioned stakeholders, is the issuance of water extraction permissions from the Great Lakes. This conflict is not only important for the authorities (the states and provinces surrounding the Great Lakes) and water related NGOs, since they have the responsibility of preserving the Great Lakes, but also crucial for businesses (e.g. water bottling, manufacturing, agriculture) and other stakeholders (e.g. municipalities seeking more water sources) which are interested in the Great Lakes to expand or improve their operations.

Regional governments push for less water usage through new regulations, and price increases. However, residents, and specially, heavy water consuming businesses, have concerns over the increasing water prices over the years. Businesses have tried to adapt to the situation through private on-site water treatment systems, to be able to reuse their wastewater a few times before sending it back to public treatment facilities. Businesses are also always looking for ways to reduce water usage through incorporating new technologies in their supply chain procedures (anonymous interviewee #3, personal communication, 2020).

Regional governments also try to regulate quality standards of the water coming into their water treatment plants. For example, the water received from businesses must meet certain requirements to be accepted into the regions' water treatment plants. This is to prevent clogging in filters and pipes, or additional costs incurred by the treatment plant to treat the unclean used water. This brings more pressure on business to adapt themselves to high standards set by these regional and local governments (anonymous interviewee #3, personal communication, 2020).

2.4.6. Water Transportation Conflicts

If and when water permission related conflicts are resolved, the method of extraction would be another potential topic of dispute. Conveying water with ships, pipelines, interbasin diversions, and water bottles are all different approaches which have been considered by stakeholders such as Region of Waterloo. However, each of these methods has financial, social, technological, and other types of advantages and disadvantages. These positive and negative aspects make each of these methods more or less preferable for the various involved stakeholders. For example, businesses might focus more on financial advantages of the approaches as compared to municipalities, which must consider long-term social effects as well. But NGOs might solely stress the environmental consequences. All of these different, opposing perspectives on water extraction methods is another source of potential disputes regarding the Great Lakes.

2.4.7. Regional and Local Water Utilities' Fragile Position in Conflicts

Municipalities (which include all local water utility management authorities such as Townships, Cities, Regional Municipalities, etc.), carry a huge responsibility regarding tens of millions of people's water supply. However, their influence and authority to manage conflicts surrounding water resources has been proven to be limited. This conclusion stems from many indicators which portray a challenging position for local water management authorities. As an example, with over 79% of Ontario population's water requirements met through municipalities, these local authorities still struggle to maintain their technical, financial, institutional, and political authority over their water systems (J. Kinkead Consulting, 2006; Kreutzwiserl and de Loe, 2001).

These challenges are intensified through numerous agreements and acts such as the 2015 Great Lakes Protection Act (Government of Canada, 2015), the Boundary Waters Treaty of 1909 (International Joint Commission, 2020), the Great Lakes Water Quality Agreement (GLWQA) first signed in 1972 and amended in 2012 (Government of Canada, 2020a), the Great Lakes Charter and Annex (Council of Great Lakes Governors, 1985), and the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (Government of Canada, 2020b). These initiatives, many of which have precedence over local municipal bylaws, municipal official plans and provincial laws (Mann, 2015), have been passed by higher level Canadian and international decisionmakers (Ronan, 2016). Although Ontario has approved regulations such as the Ontario Water Resources Act of 1990 (Government of Ontario, 2020a), and also the 1990 Public Utilities Act (Government of Ontario, 2020b) to support municipalities in managing their own water supply systems, federal and provincial power over water resources still remain intact and dominant (Kreutzwiserl and de Loe, 2001).

This superiority of various jurisdictions over local water utilities leaves a gap for in-depth investigation to analyze the approaches these regional authorities could deploy to gain a more balanced position in conflicts and disputes. This thesis provides a clearer perspective of the existing and potential conflicts for these local decisionmakers to better understand their higher-level authorities' options, and preferences. This in turn can help them adopt more informed decisions when dealing with the other involved stakeholders. These informed decisions lead to sustainably enhanced asset management, risk management, and relationships management with the customers (Rehan, Knight, Unger, & Haas, 2014; Rehan, Unger, Knight, & Haas, 2014).

2.4.8. Complexity of the Conflicts

The conflicts surrounding the Great Lakes have developed a complicated dynamic system of different options and preferences for each of the involved stakeholders. To add to the aforementioned complexity, recent developments not only in the world's political arena, but also global economic, technological, and social trends, are major variables that make this dynamic system prone to considerable changes in its status quo. For example, one of the main new external factors affecting the current state, was Donald Trump becoming the U.S. President for a period of four years. Trump's different viewpoints on climate change or other environmental challenges posed extensive pressures on environmental initiatives. Soon after he was sworn in as the 45th U.S. President, the White House Office of Management and Budget proposed funding cuts to the Great Lakes Restoration Initiative (GLRI) (from $300 million a year to about $10 million) (Matheny 2017), which raised serious concerns regarding the Great Lakes' conservation and restoration programs. These external changes should also be incorporated into the conflict for further insight into the disputes.

2.5. Knowledge Gap: Lack of an Overall Solution

As mentioned above, not only water extraction from the Great Lakes against other alternatives such as water desalination, rain barrels, or customer awareness for less water usage, can be a heated controversial dispute, but also the extraction details such as the timing, permissible amount, or methods of water extraction will soon become a serious debate among the stakeholders. Using pipelines instead of diversions, or other alternatives such as water shipping are different approaches with advantages and disadvantages which would trigger various technological, political, financial, and social concerns among activists, businesses, governments, and other decisionmakers in the water management field. After the conflict on the extraction itself, and the details of water extraction have been resolved, the involved stakeholders might fall into another disagreement regarding setting water treatment standards before pouring the used water back into the Great Lakes (Figure 2.2).

The same applies to conflicts which are extended in time. For example, the Great Lakes being polluted is a concern which has been the center of attention for several decades. There have been peaks of high phosphorous levels in Lake Erie and disputes on this matter in 1970s and also in 2010s. Therefore, the more recent increase in pollutant levels and the disputes surrounding it, should be investigated with having those previous conflicts in mind.

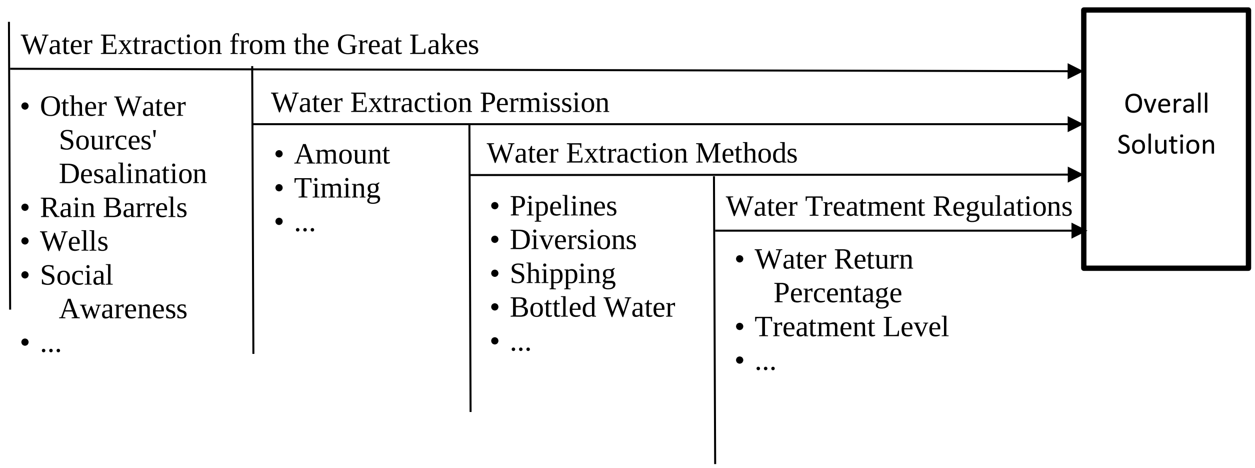

Figure 2-2: Inter-related Conflicts Diagram for the Great Lakes

These various conflicts, which come one after another, and also the numerous uncontrollable external variables affecting the stability of the current status, develop a multiphase set of inter-related disputes which complicate matters among the stakeholders, making them more difficult to resolve or predict. One approach to conflict resolution is to provide independent solutions for each of the different conflicts occurring among the stakeholders in the various phases they interact. Various methods apply this approach to solving the conflicts independently from each other. For example, some have investigated the stakeholders' behaviors through game theory (e.g. Madani 2010).

Dealing with each of these conflicts separately carries several disadvantages. An important limitation is that some scenarios in a conflict might not even have to be investigated since they are infeasible based on the previous conflicts, but without knowledge of the previous conflicts' details, one cannot understand or eliminate those infeasible scenarios. One other limitation of analyzing the disputes independent of each other is that preferences and behavior of the stakeholders may not be understood in depth, when the researcher is solely focused on one single conflict. The roots of a heated conflict might actually lie somewhere beyond the current conflict’s boundaries. Another concern in the traditional approach is that a new option might be added to a conflict because of an event in the previous conflicts. Although these new options or hidden infeasible scenarios might be researched and recognized when using the previous methods, if the conflicts are analyzed together, these intricacies could be investigated easier and with less effort. Moreover, going through each conflict separately does not guarantee insightful perspectives toward future conflicts.

In sum, the existing conflict resolution methods do not consider the various conflicts among the involved decisionmakers as a continuous thread of disputes (e.g. Schlager, and Heikkila, 2009). They focus on each conflict independent from other disputes and try to describe the situation or predict approaches to resolve the issue at hand without considering the other disputes among the decisionmakers. These approaches clearly have many limitations and thus, in the current line of research the objective is to provide an overall solution to the long line of conflicts happening or to-be-happening among the decisionmakers. This brings advantages to the involved stakeholders, as they would become aware of the different scenarios, which might occur in different phases of their interactions with the other stakeholders. Moreover, the uniqueness and importance of the Great Lakes, as mentioned before, necessitates a comprehensive approach so that details and smaller conflicts are investigated intricately. Many have studied the Great Lakes’ disputes, however, depicting all the conflicts in one single framework carries an added value that should be sought.

To further illustrate the value that this thesis is adding to the literature, multiple papers were selected from the large body of literature reviewed, and they were analyzed to more clearly illustrate the knowledge gap being filled by this thesis (e.g., Kodikara et al., 2010; Kuang, 2015; Martin-Ortega and Berbel, 2010; Matrosov, Woods, & Harou, 2013; Yan et al., 2017; Yin, Huang, & Hipel, 1999). These papers' contributions are summarized in Table 2.1. The papers analyzed were categorized into four topics: Great Lakes, water conflicts, conflict analysis methods, and papers including studies of interconnected series of conflicts. Most of the papers have covered more than two of the aforementioned topics, except for five which provide in-depth insight into either conflict analysis methodologies or water conflicts (i.e., Hakvoort, 2010; Osman and Nikbakht, 2014; Schlager and Heikkila, 2009; Walk, 2011; Zeitoun, and Warner, 2006). The previously discussed knowledge gap can be better understood when going through Table 2.1. Each of the mentioned papers discuss one or a couple of the four dimensions of the greater problem discussed in the preceding paragraphs; none has addressed all the key problem dimensions, as the synthesis at the core of this thesis attempts to do.

Table 2.1 Summary of Investigated Papers Related to this Thesis

	Authors, Date	Title	Great Lakes	Water Conflicts	Conflict Analysis Methods	Series of Conflicts	Contribution
1	Becker N., & Easter W., 1995	Water Diversions in the Great Lakes Basin Analyzed in a Game Theory Framework	✓	✓	✓	-	Using different game theory approaches (with 1, 2, and 10 decisionmakers) to model and analyze water extraction conflicts among 8 States of US and 2 Provinces of Canada based on economic factors
2	Wolf A.T., 1997	International Water Conflict Resolution: Lessons from Comparative Analysis	✓	✓	-	-	Based on combining past treaty negotiations, investigating case studies, and reviewing forums on international waters, offers insights for water conflicts.
3	Madani K., 2010	Game Theory and Water Resources	-	✓	✓	-	Illustrates different kinds of water resource problems and reviews the applications of game theory methods through a series of non-cooperative water resource games.
4	Vieiraa Z.M.C.L., & Ribeirob M.M.R., 2010	A Methodology for First- and Second-order Water Conflicts Analysis	-	✓	✓	-	Using conflict theory concepts, analyzes first-order (water resources scarcity) and second-order (social resources scarcity) water conflicts.
5	Hakvoort I., 2010	The Conflict Pyramid: A Holistic Approach to Structuring Conflict Resolution in Schools	-	-	✓	-	Investigates applying the Conflict Pyramid approach by Richard Cohen, to resolve conflicts in education programs.

	Authors, Date	Title	Great Lakes	Water Conflicts	Conflict Analysis Methods	Series of Conflicts	Contribution
6	Becker N., & Easter K.W., 1999	Conflict and Cooperation in Managing International Water Resources Such as the Great Lakes	✓	✓	✓	-	Uses the game theory approach to demonstrate the potential for cooperative management of open access water resources.
7	Schlager E., & Heikkila T., 2009	Resolving Water Conflicts: A Comparative Analysis of Interstate River Compacts	-	✓	-	-	Explores different types of interstate water agreements and how they contribute to resolving or exacerbating water conflicts.
8	Hipel K.W., Obeidi A., Fang L., & Kilgour D.M., 2018	Adaptive Systems Thinking in Integrated Water Resources Management with Insights into Conflicts over Water Exports	-	✓	✓	-	Discusses the application of GMCR in multiple participant, multiple criteria conflicts regarding water export.
9	Zeitoun M., & Warner J.Z., 2006	Hydro-hegemony – a Framework for Analysis of Trans-boundary Water Conflicts	-	✓	-	-	Using a hydro-hegemony bulk framework to analyze and leadership transboundary water conflicts.
10	Kreutzwiser R.D., & de Loë R.C., 2002	Municipal Capacity to Manage Water Problems and Conflicts: The Ontario Experience	✓	✓	-	-	Assesses financial, structural, political and other types of abilities of local municipalities to resolve water related conflicts.
11	Hipel K.W., 1992	Multiple Objective Decision Making in Water Resources	-	✓	✓	-	Conducts a thorough investigation into multi-objective decision-making techniques in water resources.

	Authors, Date	Title	Great Lakes	Water Conflicts	Conflict Analysis Methods	Series of Conflicts	Contribution
12	Madani K., & Hipel K.W., 2011	Non-Cooperative Stability Definitions for Strategic Analysis of Generic Water Resources Conflicts	-	✓	✓	-	Reviews stability definitions, which are applicable in non-cooperative water resources games.
13	Walk S.R., 2011	A New Fast, Reliable Filtering Method for Multiple Criteria Decision Making	-	-	✓	-	Uses filtering of alternatives approach to investigate complex conflicts (multi-criteria decision environments).
14	Cai X., Lasdon L., & Michelsen A.M., 2004	Group Decision Making in Water Resources Planning Using Multiple Objective Analysis	-	✓	✓	-	Investigates combinations of multi-objective analysis and multi-participant, multi-criteria decision-making methods for group decisions in water resources planning.
15	Mirchi A., Madani K., Watkins Jr. D., & Ahmad S., 2012	Synthesis of System Dynamics Tools for Holistic Conceptualization of Water Resources Problems	-	✓	✓	-	Discusses the application of system dynamics in systems thinking regarding water resources systems.
16	Madani K., Lund J.R., 2011	A Monte-Carlo Game Theoretic Approach for Multi-Criteria Decision Making Under Uncertainty	-	✓	✓	-	Investigates using non-cooperative game theory concepts (e.g. the Monte-Carlo approach) to model and solve multi-criteria decision-making problems without requiring weighting for any criteria.

	Authors, Date	Title	Great Lakes	Water Conflicts	Conflict Analysis Methods	Series of Conflicts	Contribution
17	Osman H., Nikbakht M., 2014	A Game-Theoretic Model for Roadway Performance Management: A Socio-Technical Approach	-	-	✓	-	Proposes a game theoretic framework that quantitatively analyzes the interaction between social and physical networks of assets.
18	Talukder B., Hipel K. W., 2020	Diagnosis of Sustainability of Trans-Boundary Water Governance in the Great Lakes Basin	✓	✓	-	-	Conducts a thorough literature review which shows a positive relationship between Trans-boundary water governance and reducing tensions and achieving sustainability goals in the Great Lakes basin.

Chapter 3 Methodology

3.1. Methodology Background

In this section, an introduction is provided regarding causal loop diagrams in System Dynamics (SD) analysis, and also, Graph Model for Conflict Resolution (GMCR), external analysis, scenario analysis, and Multi-Participant Multi-Criteria (MPMC) methods. Then, the proposed method for the current project, which is a combination of the aforementioned approaches, is discussed.

3.1.1. Causal Loop Diagrams

System dynamic (SD) analysis is based on the notion that complex structures' components are in continuous, and in many cases, time-delayed relationships which affect their behavior (Forrester, 1961). Using well-researched qualitative and quantitative causal loops and equations, an SD analysis depicts a map of the components of a system, providing a better understanding of their relationships (i.e. dynamics), which in turn, sheds light on the past, current, and possible future actions of the various components of the system.

The initial step in an SD analysis is the development of causal loop diagrams. In this phase, the interactions among the decisionmakers and other components of the system are shown in a simple graphical representation. The influence of each component on other components can be positive or negative, developing a combination of positive and negative feedback loops, which are linked together in a broader system. Causal loop diagrams are developed qualitatively and do not provide the detailed insight required for an in-depth analysis of the system. For this, stock and flow diagrams are developed, which quantitatively study accumulation and depletion of the system's components in time (Nasiri et al., 2013).

This thesis utilizes the first step of the SD approach (i.e. development of the causal loop diagrams), to initially investigate the interactions among the components of water conflicts' complex systems. The causal loop diagrams of the conflicts assist in investigating decisionmakers' options, and each option's effects on other decisionmakers' actions and options. The output of each causal loop diagram analysis is then employed to conduct a well-researched GMCR analysis on each of the conflicts of interest.

3.1.2. The Graph Model for Conflict Resolution Method (GMCR)

The Graph Model for Conflict Resolution Method (GMCR) (Fang et al., 1993; Kilgour et al., 1987) is a conflict resolution method developed to enhance understanding of complex disputes occurring among two or more decisionmakers. It consists of two parts: modeling and analysis (Figure 3.1) (Hipel, Fang, & Kilgour, 2020).

In the first step of the modeling stage, the situation is thoroughly investigated, and the main decisionmakers playing a role in the conflict are identified. Each system has several stakeholders who directly or indirectly affect or are affected by the conflict. However, only the most influential decisionmakers are brought into the model to avoid over-complicating the modelled system (Hipel and Fang, 2021; Hipel et al., 2020).

The next step is to understand the available option(s) for each decisionmaker. These options are the different possible decisions a decisionmaker can select and act upon. The different combinations of the decisionmakers' options form various states (Fang et al., 1993).

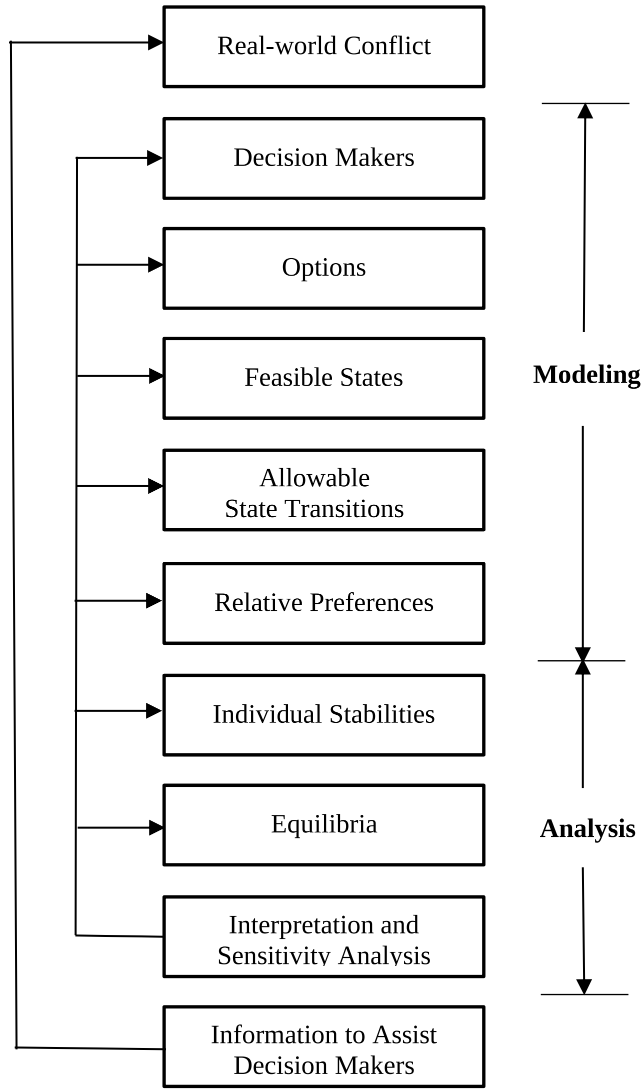

Figure 3-1: Standard Graph Model (Fang et al., 1993)

For example, if there are two decisionmakers and each of them have three options, there would be 2^6 states, which equals to 64 states in total. Although the total number of states developed from the different combinations of the options sum up to 64, not all of these states are feasible in the real world. To narrow down the states to the feasible ones, concepts such as "mutually exclusive option elimination" should be implemented. For instance, in a situation in which a decisionmaker has two options: to repair the pipeline, and to change the pipeline altogether, it is not feasible to simultaneously choose both options in the real world. Therefore, the states that have both of these chosen options as happening together are infeasible and would be eliminated from the model (Hipel et al., 2020; Xu, Hipel, Kilgour, & Fang, 2018).

After identifying all possible and feasible states which could occur in the conflict, each decisionmaker's preferences would be ranked ordinally, from the most preferred state to the least preferred state. So, a state which puts a decisionmaker in an undesirable position is ranked lower in the decisionmaker's preference list and the decisionmaker would rather not transition to that state from another more preferred state (Hipel and Fang, 2021; Hipel et al., 2020).

If a decisionmaker transitions from a state to another state which is more preferred for that particular decisionmaker, it has gone through a unilateral improvement (UI). The most preferred situation for a decisionmaker is when it prefers to stay in that state, and not transition (i.e. unilaterally improve) to any other state (Fang et al., 1993; Hipel and Fang, 2021).

After the different options, states, preferences, and unilateral improvements of all the conflict's decisionmakers are identified, a visualizing technique called the Graph Form can aid in better investigating the conflict's different potential outcomes (Hipel et al., 2020).

The above definitions can be standardized and formulated as below. All definitions are extracted from Fang et al. (1993).

3.1.2.1. Definition 1. The Graph Model for Conflict Resolution (GMCR)

G= [N,S ,$(A_i)_{i\epsilon N}$,$(\succcurlyeq_i)_{i\epsilon N}$)], and is called a *standard graph model*.

The set of all decisionmakers (DMs) is N, where $|N| \geq 2$.

The set of all feasible or distinguished states in the conflict is S, (S,A_i), where $2 \leq |S| \leq N$. Also S_0 is specified for the status quo (current state).

For each DM $i \in N$, $A_i \subset S \times S$ is the set of state transitions or set of all arcs controlled by *i*. In other words, A_i is the set of unilateral available moves for DM *i*.

(s_1, s_2) is an arc in DM *i*'s directed graph, if DM *i* can reach, in a one-step transition, state s_2 from state s_1.

DM *i*'s preference on S is shown by a pair of binary relationships $\{\succ_i, \sim_i\}$ on *S*; where $s_2 \succ_i s_1$ means DM *i* prefers s_2 to s_1, and $s_2 \sim_i s_1$ means DM *i* equally prefers s_2 and s_1. The relationship $s_2 \succcurlyeq_i s_1$ means that DM *i* prefers state s_2 to s_1 or equally prefers s_1 and s_2.

In a standard graph model, based on DM *i*'s elicited preferences over states, *S* can be partitioned into two sets, relative to a particular state $s \in S$ (i.e., *s* is being assessed for stability), as follows: $\Phi_i^+(s) = \{s_m \in S : s_m \succ_i s\}$ is the set of all states that DM *i* prefers to state *s*; and $\Phi_i^{\leq}(s) = \{s_m \in S : s \succcurlyeq_i s_m\}$ is the set of all states that DM *i* finds equally or less preferred to state *s*.

(1) $\succ_i$ is asymmetric; hence, for all $s_1, s_2 \in$ S, $s_1 \succ_i s_2$and $s_2 \succ_i s_1$ cannot hold simultaneously.

(2) $\sim_i$ is reflexive; thus, for any $s_1 \in$ S, $s_1 \sim_i s_1$.

(3) $\sim_i$ is symmetric; i.e, for all $s_1, s_2 \in$ S, if $s_1 \sim_i s_2$ then $s_2 \sim_i s_1$.

(4) $\{\succ_i, \sim_i\}$ is complete; thus, for all $s_1, s_2 \in$ S, exactly one of $s_1 \succ_i s_2$, $s_2 \succ_i s_1$ or $s_1 \sim_i s_2$ is true.

3.1.2.2. Definition 2. Reachable List

For $i \in N$, and $s \in S$ DM *i's reachable list from state s is the set* $\{s_2 \in S | (s_1, s_2) \in A_i\}$ denoted by R_i(s) ⊂ S. When individual DMs unilaterally cause transitions (unilateral move (Ums)) among states from an initial state, or *status quo*, to a final state that is stable for all DMs.

3.1.2.3. Definition 3. Unilateral Improvement (UI) List for Each Decisionmaker

In the Graph Model, the set of all states that DM *i* can unilaterally reach from state $s \in S$ in one step is the reachable list R_i(s). A UI from a particular state for a specific DM is a preferred state for that DM to which he or she can unilaterally move in one step. R_i(s)'s two subsets are: R_i^+ (s) = R_i(s) ∩ $\Phi_i^+(s)$ is the set of all UIs from state s for DM i; and $R_i^{\leq}$(s) = R_i(s) $\Phi_i^{\leq}(s)$ is the set of all unilateral disimprovements and equally preferred states from state s for DM i.

Now that a comprehensive model of the situation is developed, the researcher should have a thorough understanding of the dispute and can initiate the analysis phase.

In the first step of the analysis section, possible stable states for each decisionmaker are determined. This step is called Individual Stability Analysis. Initially, a comprehensive examination of possible moves and countermoves by the decisionmakers in the conflict is provided. Individual Stability Analysis lays out answers to "what if" questions. For example, what happens if Decisionmaker A changes its decision on Option 1, and thus, the conflict changes from State 1 to State 3? Then, can Decisionmaker B unilaterally improve from State 3 to State 5? And if that happens, is State 5 less or more preferred for Decisionmaker A, who initially decided to move from State 1? Each of these scenarios are examined in the Stability Analysis phase, and all possible outcomes are developed through the use of mathematically developed solution concepts. The definitions of these solution concepts is provided below in Table 3.1.

Through the use of these four solution concepts, stable states for each decisionmaker are determined. This refers to a state which is not advantageous for the decisionmaker to move away from. At the end of the Stability Analysis, states which are stable under each solution concept for all decisionmakers, are called equilibrium states and would be proposed as a possible resolution to the dispute. A Nash or SEQ stable state for all decisionmakers is a strong equilibrium. These equilibria reflect actual outcomes which occur in reality. However, a GMR or SMR state for all decisionmakers constitutes a weak equilibrium. These equilibria depict outcomes which are less likely to happen (He, 2015). Therefore, although all the four solution concepts are calculated and presented in the appendices, Nash and SEQ states are presented as the final equilibria in the results section of this thesis.

Table 3.1 Solution Concepts (Fang et al. (1993))

Solution Concepts	**Stability Description**
Nash stability (R)	"A focal decisionmaker cannot unilaterally move to a more preferred state"
General Metarationality (GMR)	"All of the focal decisionmaker's unilateral improvements are sanctioned by subsequent unilateral moves by others"
Symmetric Metarationality (SMR)	"All of the focal decisionmaker's unilateral improvements are still sanctioned even after a possible response by this decisionmaker"
Sequential stability (SEQ)	"All of the focal decisionmaker's unilateral improvements are sanctioned by subsequent unilateral improvements by others"

The above solution concept definitions can be standardized and formulated as below. All definitions are extracted from Fang et al. (1993).

3.1.2.4. Definition 4. Nash Stability (Rationality)

For $i \in N$, a state $s \in S$ is Nash stable for DM i, denoted by $s \in S^{Nash_i}$, iff R_i^+ (s) = Ø. Under the Nash solution concept, a DM will move to a more preferred state whenever possible, without regard to any possible countermoves by the opponent.

3.1.2.5. Definition 5. General Metarationality (GMR)

For $i \in N$, a state $s \in S$ is general metarational stable for DM i, denoted by $s \in S^{GMR_i}$, iff for every $t \in R_i^+$ (s) there exists R_j (t) $\cap \Phi_i^{\leq}(s) \neq$ Ø. Thus, a state s is general metarational stable for

DM *i* iff for every UI *i* can take advantage of, the opponent, DM *j*, can subsequently move to a state that is at most as good for *i* as the original state *s*.

3.1.2.6. Definition 6. Symmetric Metarationality (SMR)

For $i \in N$, a state $s \in S$ is symmetric metarational stable for DM *i*, denoted by $s \in S^{SMR_i}$, iff for every $t \in R_i^+$ (s), R_j (t) $\cap \Phi_i^{\leq}(s) \neq \emptyset$, and for all $h \in R_j$ (t) $\cap \Phi_i^{\leq}(s)$, R_i(h) $\cap$ $\Phi_i^+(s) = \emptyset$. A state *s* is symmetric metarational stable for DM *i* iff not only every UI for *i* from *s* is sanctioned by the opponent, but no unilateral counterresponse by DM *i* can leave it better off than the original state *s*.

3.1.2.7. Definition 7. Sequential Stability (SEQ)

For $i \in N$, a state $s \in S$ is sequentially stable for DM *i*, denoted by $s \in S^{SEQ_i}$, iff for every $t \in R_i^+$ (s) there exists R_j^+ $(t) \cap \Phi_i^{\leq}(s) \neq \emptyset$. A state *s* is sequentially stable for DM *i* iff every UI for *i* from *s*, state *s* is *credibly sanctioned* by the sanctioner DM *j*.

After equilibrium states are identified, sensitivity analyses can be conducted to evaluate and validate the robustness of the analysis results. In this phase, changes in the model parameters are applied to examine the model. These changes can vary from decisionmaker preference changes, to adding or modifying their options. Analyzing the effects of these changes on the new equilibrium states would help the researcher validate the previously developed model.

To employ the GMCR, a comprehensive decision support system called the GMCRII (Fang, Hipel, Kilgour, & Peng, 2003a; Fang, Hipel, Kilgour, & Peng, 2003b; Hipel, Kilgour, Fang, & Peng 1997) is used in this thesis. The GMCRII implements delicately designed data structures and algorithms to generate possible states, eliminate infeasible states, and specify potential state transitions. It also develops a comprehensive graph model of the conflict through the use of algorithms which rank preferences of the decisionmakers. This decision support system contributes to better studying real world conflicts based on the GMCR methodology (Fang et al., 2003a; Fang et al., 2003b).

3.1.3. External Analysis

After a conflict is studied with previous related conflicts analyses acting as its inputs, an in-depth understanding of the stakeholders, and their current and previous options, preferences, and relationships with other stakeholders playing a role in the conflict in interest is developed.

This thorough set of information gives us valuable insight into the current status of the system. However, the current status quo and equilibria (future possible stable states for all decisionmakers), are mostly based on the stakeholders' relationships and their decisions, which are highly influenced by their options and preferences. In other words, GMCR builds a system which is developed internally, depending on the stakeholders' situations. The developed equilibria do not factor in the possible, yet important, external variables when predicting the future of the conflict.

Non-sudden changes might be considered by the stakeholders when making decisions, but in most cases, sudden changes or external shocks which might hugely affect the status quo, or significantly change the equilibriums are not examined when conducting SDs or GMCRs. This is the reason why conducting an external analysis and scenario analysis is proposed in the current presented framework, to close the gap when predicting future possible happenings in a conflict.

As discussed previously, the external environment has a huge effect on ongoing conflicts among the stakeholders. These external variables affect, and are affected by the stakeholders, but cannot be controlled by them. For example, flooding, changes in the higher political ranks of the country, a national economic recession, unprecedented population growth, are all external variables which negatively or positively affect all the stakeholders such as the government, businesses, and NGOs, yet none of these decisionmakers can completely prevent them from happening.

These external variables change the dynamics of the relationships in a conflict, especially when they occur instantly, and act as a sudden shock to the system. In these instances, the stakeholders are not prepared for the occurrence, and their status in the system changes suddenly. This might raise even more conflicts among the stakeholders, since they are suddenly confronted by more issues to process and resolve, on top of the previously existing disputes.

Such external variables have been categorized in various models. One of the more common models used in investigating external variables for strategy formulation, is the PESTLE (Aguilar, 1967; Perera, 2017). The letters of the model name stand for: Political, Economic, Social, Technological, Legal, and Environmental variables. In this model, possible occurrences within each of these six categories and their effects on the related situation are studied (Aguilar, 1967; Perera, 2017).

For example, what will happen if a president or prime minister of a country is replaced by another, different in perspective from the previous one? How will this political change affect the dynamics of the conflict under study? Would the stakeholders' options or preferences change in light of the new political environment? Would this change be in their favor, enhancing their position in the disputes they have with others? Moreover, would this political change bring with itself a legal shock as well? Would laws or regulations relevant to the dispute also change? How would this legal change influence their current options' feasibility? Legal changes might increase or decrease operational costs of the decisionmakers involved in the dispute. A legal change might also increase the time and effort one must contribute for a certain performance level. A legal change might also change authority powers of the disputes' stakeholders (Aguilar, 1967; Perera, 2017).

In addition to the external political and legal variables, social and demographic changes can also influence a conflict's system. For example, social trends can influence the dynamics of a dispute. When people of the society become aware of environmental crises or climate change consequences, they change their buying and consuming behaviours, which affects relevant businesses in a positive or negative way.

A huge flood might also increase or decrease the resources available to a business, and this affects its power over other stakeholders in relation with that business. This represents the external environmental variable of the PESTLE model.

Using PESTLE as an external variable analysis in the current proposed framework, provides us with the external perspective, required after conducting the GMCR. After studying the various external factors, which might affect the conflict's system dynamics, enough information exists to discuss possible future happenings.

3.1.4. Scenario Analysis

Decision making regarding natural (e.g. water) resources management usually involve various uncertain variables, present in complex social systems with profound uncertainties (Harwood & Stokes 2003; Kujala, Burgman, & Moilanen 2013; Ludwig, Hilborn, & Walters 1993). Although data collection inconsistencies, and other issues exist when making decisions, the failures in natural resources management interventions can be explained, to a high extent, by these uncertain variables (Punt & Donovan 2007).

Because of this, various support tools have been developed to reduce these uncertainties, increase system dynamics transparency, and assist in decision-making. These tools enhance system dynamics exploration, stakeholder investigation, and potential future prediction (Bekessy and Selinske, 2017). One of these tools is scenario analysis, in which multiple points of view are gathered and shared to create alternative views of the future. Scenario planning as a method of investigating shocks in social decision-making systems, has been frequently used in the recent literature.

Scenarios are used to come up with enhanced plans to act in face of different possible situations. Scenarios also provide flexibility for the management of conflicts. In developing scenarios, a focus question is asked, and the different scenarios are developed in an attempt to answer that question. The focus question acts as an initial anchor before proceeding to the analysis section, since it establishes the main question to be answered during the analysis process.

The most important benefit of scenario planning is that it helps the stakeholders to be proactive in the face of uncontrollable external variables. Being reactive, as opposed to being proactive to problems when they arise, limits the ability of the decisionmaker to spend time on strategizing and planning before implementing any solutions to the problem. Being able to project returns or losses of different possible futures, before they occur, saves time, and increases the quality of the decisions, since they have been developed in calm and no-stress conditions.

The scenarios analyzed in this thesis, are developed based on a “bottom up” approach, which has been used in a few previous research (e.g., Bizikova et al. (2011), Gidley et al. (2009), Kok et al.

(2007), Svenfelt et al. (2010), Höjer et al. (2008), and Burch (2010)). One of the main features of this approach is that the stakeholders of the topic-of-interest play a major role in constructing the key scenarios (Chermack 2004; Shaw et al. 2009). The idea behind this, is that since the stakeholders will be the main decisionmakers should any of those scenarios turn into reality, it is best that they are involved in the process of investigating them, so that the stakeholders are engaged in tailor-making the scenarios built around their concerns. This approach prevents conforming to global perspective scenarios, which have already been developed by other institutions. For example, several climate change scenarios have been constructed by international institutions such as the UN, however, investigating customized scenarios for specific regions or system dynamics, is much more effective in understanding certain situations.

A major limitation of using the bottom-up approach when developing scenarios is that it is generally time-consuming and/or costly, since stakeholder involvement (i.e. data collection through interviews) requires more time and effort than merely gathering information through secondary data gathering methods. However, using interview guidelines is proposed to speed up the scenario development process.

In this thesis, the PESTLE model is used as a starting point in developing the scenarios. In this approach, the interviewees are asked open-ended questions, to gather their input on different possible occurrences within each of the six PESTLE model factors. For example, questions might follow a similar flow to the following: In thinking about uncontrollable economic factors, what might be a reason for you to wake up in the middle of the night? What are the biggest uncertainties relevant to this issue which cause you concern? If this economic issue does actually occur, how do you think yours and the other stakeholders' positions would change in the dispute? What options would you think you might have, and what key decisions do you think you should make, should this economic shock/change occur?

After gathering all information from the stakeholders, scenario narratives should be written to develop a thorough perspective on each possible scenario. The purpose here is to tie all the ideas and previous information into one or a few scenario narratives. The scenario narratives provide support for the decisionmakers to take different courses of action in different conditions.

3.1.5. The Multiple Participant Multiple Criteria Decision Making

The MPMC (Multiple Participant Multiple Criteria) approach is a method used to analyze situations in which multiple decisionmakers with multiple objectives or preferences are involved (Hipel, Radford, & Fang, 1993) (Figure 3.2). This means that each decisionmaker considers multiple criteria when trying to decide upon a course of action when faced with other decisionmakers.

An example for a Single Participant Multiple Criteria (SPMC) decision can be when one person is trying to select and buy a car among other cars, having in mind different colors, makes, models, and other factors (i.e. different criteria). A Multiple Participant Single Criteria (MPSC) occasion is when four family members must rank their preferred cars using one single criterion (i.e. the color of the car). An MPMC situation, however, is when the four family members are to decide about the car as a group, using various criteria. Needless to mention that each individual (decisionmaker) has a different preference and thus, different opinion in the decision-making process.

The following are components of the method (Hipel et al., 1993):

A set of Decisionmakers (DMs), $\{DM_i$, i = 1, 2, . . ., n},

A set of states, $\{U_j$, j = 1, 2, . . ., m}, resulting from possible actions by the DMs,

A set of criteria, $\{C_{ik}$, k= 1, 2, . . ., $l_i\}$, for DM i, i = 1, 2, ..., n,

A set of evaluations, $\{P_{ijk}$, j = 1, 2, . . ., m}, for DM i, i = 1, 2, ..., n, and criterion k, k = 1, 2, ..., l_i, with respect to the set of states, $\{U_j$, j = 1, 2, ..., m}.

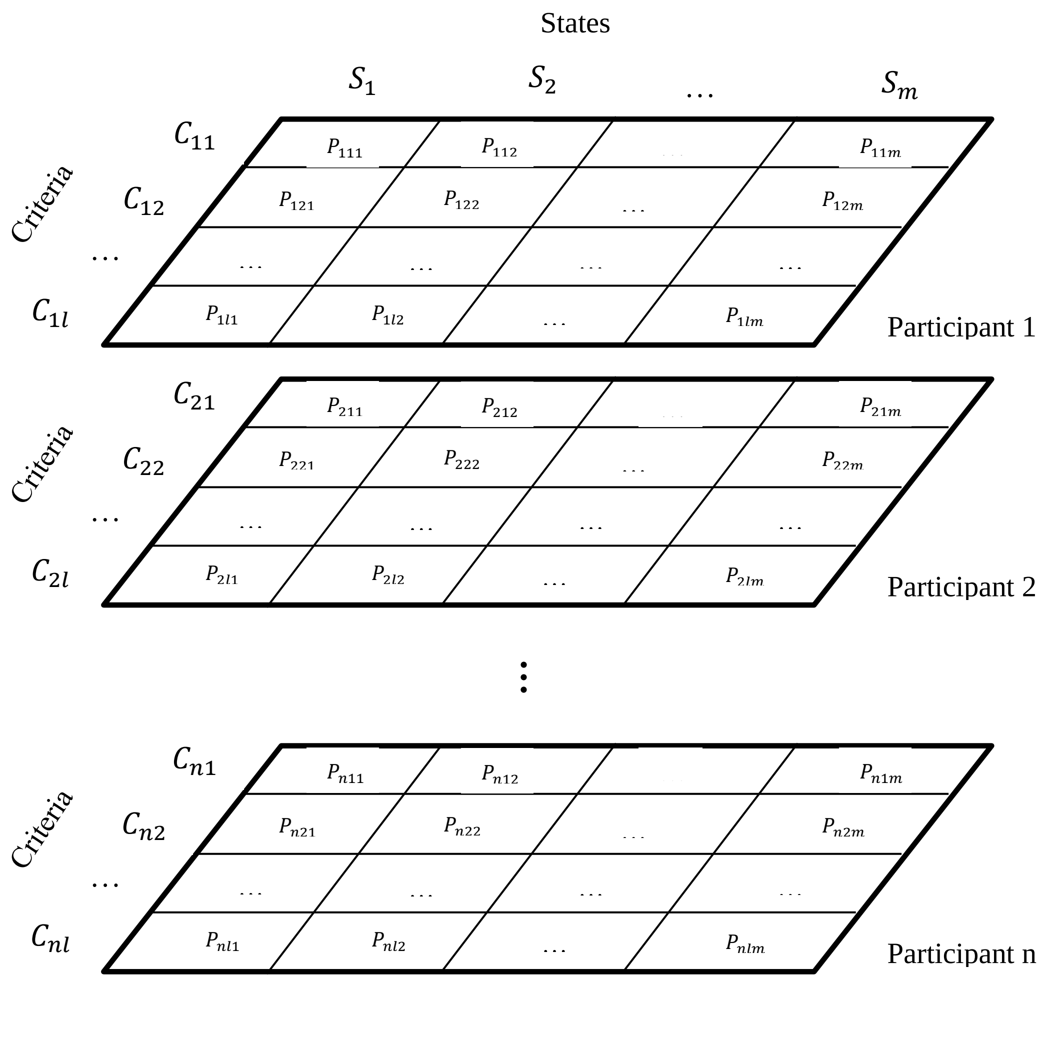

Figure 3-2: Multiple Participant – Multiple Criteria Decision Making (Hipel et al., 1993)

Although each decisionmaker is confronted by an SPMC situation when dealing with their own criteria, the MPMC attempts to resolve the conflict considering all the decisionmakers' objectives as compared to only one. Then, using Multiple Criteria Decision Analysis (MCDA), each participant's decision is finalized independent from the other decisionmakers. There are various MCDA methods which can be used to solve such cases. For example, the Analytic Hierarchy Process (AHP) systematically ranks the participant's preferences by comparing them to each other two at a time. The result is a prioritized list of states for each participant based on the different criteria each of them hold for themselves. In this thesis however, MCDA is conducted using the Graph Model for Conflict Resolution (GMCR) preference tables, which are discussed more in detail later on. After an MCDA is conducted (either through AHP, GMCR preference tables, or other methods) for each single participant, a final ranking of the available states is developed to investigate the situation as a whole (Hipel et al., 1993).

3.2. Methodology Used for this Thesis

As mentioned previously, conflicts over the Great Lakes are complex and can occur simultaneously or one after another. One approach is to provide solutions for each of those conflicts independently from the other disputes. However, another approach, which is used here, is to investigate each conflict having in mind the previous and future conflicts (Figure 3.3).

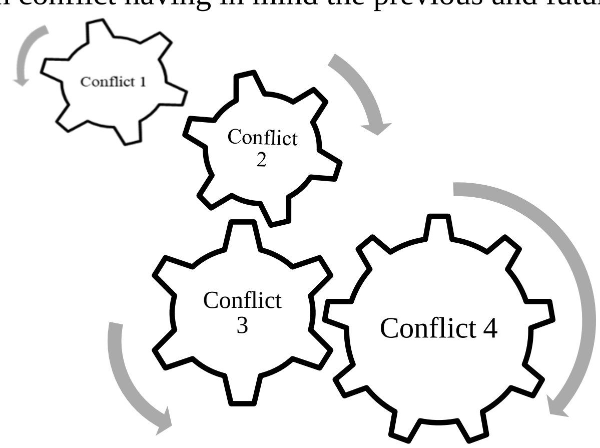

Figure 3-3 Analyzing Interrelated Conflicts

For example, the 2010s conflict over increasing pollutants in Lake Erie is analyzed with having the 1970s conflicts and context in mind. Possible biases and previous preferences that each of the decisionmakers had in the previous disputes are brought into account, and this gives useful insight into the next phases' conflicts, providing yet better solutions and predictions.

For a better understanding of this method, the different phases of data collection and analysis are discussed here (Figure 3.4). Initially, to get to an overall view of, and hence solution for a conflict, the current dynamics are studied and shown in a causal loop diagram. The development of the diagram feedback loops provides insights into the relationships among the decisionmakers. This is an important, yet challenging phase of the project. Reliable, valid information regarding each of the decisionmakers is hard to obtain, and understanding relationships between each of them is another difficult part of this phase. In this phase, the multiple interrelated conflicts among the decisionmakers are extracted using the information review process.

After the current-status diagram is created using the gathered information, preferences and options of the stakeholders are investigated and categorized. Then, the various potential conflicts among the decisionmakers are determined and analyzed in detail. This is done through the GMCRII decision support system which is based on the GMCR methodology. After this phase is completed, not only the current status of each of the involved decisionmakers are assessed, but also their relationships and interrelated conflicts, plus the suggested solutions (i.e. equilibria for the stakeholders) for each of these and future disputes are determined.

After this initial conflict investigation has concluded, the same process is applied to the next conflict in interest. However, the previous conflict analysis conclusions are also used as information inputs for the next conflict analysis. Using this approach, the history of the conflicts are also thoroughly investigated to provide a broader perspective of the system.

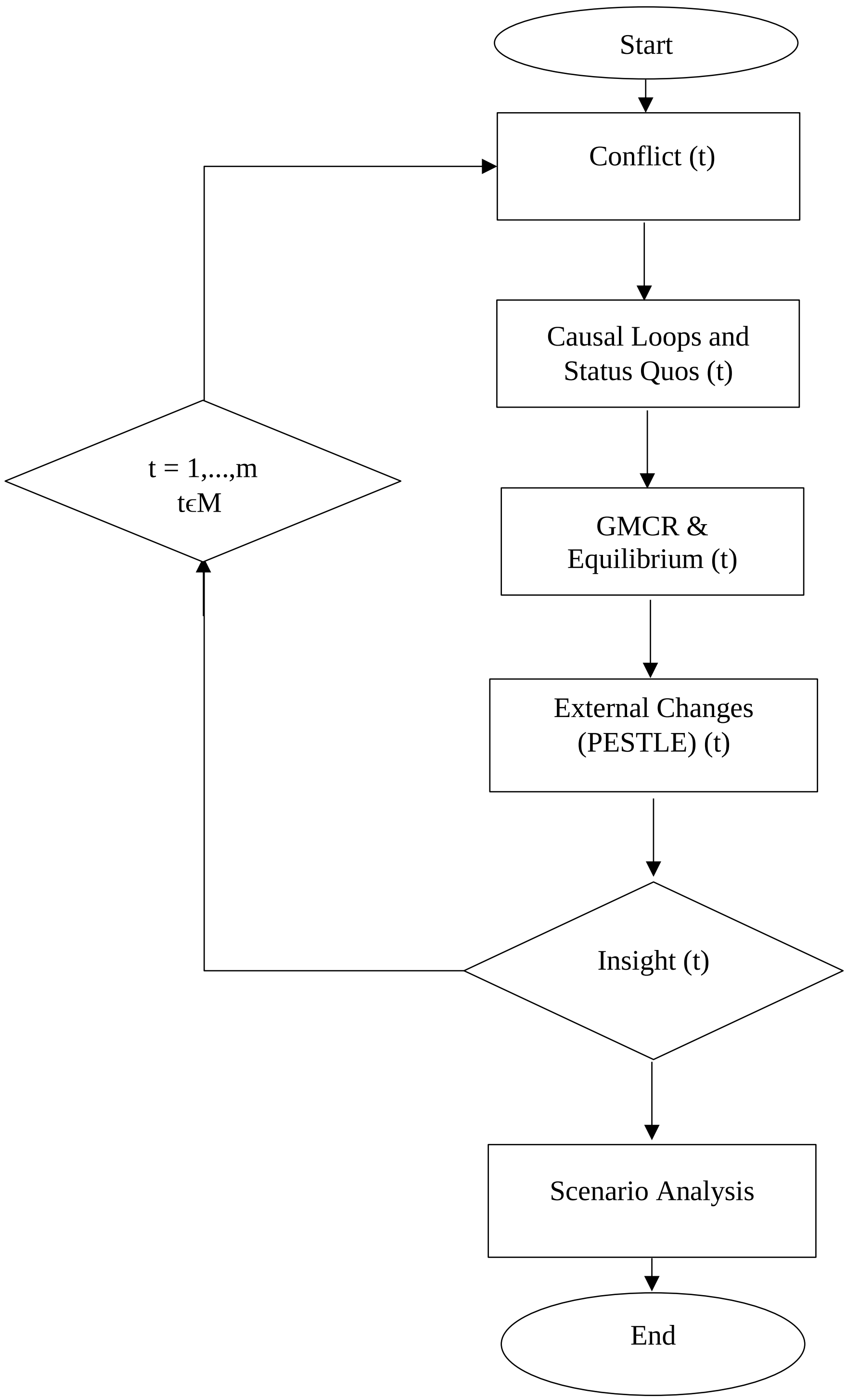

Figure 3.4 Phases of the Currently Used Methodology

The external variables affecting the current status of the decisionmakers, and the ongoing and future conflicts among them should also be considered. These external variables are studied using the PESTLE analysis approach. This tool gives us insight into external factors in the following six categories: political topics (e.g. governmental instabilities), economic concerns (e.g. inflation rates), social trends (e.g. water awareness), technological happenings (e.g. water extraction techniques), legal changes (e.g. water treatment standards), and environmental issues (e.g. floods) (Aguilar, 1967; Perera, 2017).

Each of these external factors develop shocks, potentially greatly changing the current status of the decisionmakers, and the dynamics of the current systems. The ongoing conflicts will also likely change due to these external happenings. Discussing these external variables provide different scenarios regarding each of the conflicts, better preparing the decisionmakers to deal with them. In this phase, all possible consequences of a conflict are determined.

3.3. Data Collection

3.3.1. Secondary Data Collection

Information regarding the current status of the stakeholders (and other parts of this thesis) is collected from multiple sources, varying from peer reviewed published papers to verified media articles. These sources shed light on the previous and ongoing disputes among the decisionmakers involved in the Great Lakes. Moreover, reviewing and bringing in relevant journal articles, which describe the methodologies used in this thesis, are also of high importance.

3.3.2. Primary Data Collection: Interviews

Another source, which is used to collect data and also to verify the already gathered information, is interviewing stakeholders involved in the Great Lakes conflicts. These interviews are helpful in gaining insight into the decisionmakers' preferences and roots of the current and potential conflicts among the decisionmakers.

3.3.2.1. Interview Process

The below process took place regarding each individual selected for interviewing.

- Through thorough investigation of the secondary data from the previous step, potential interviewees were identified. Some of these individuals were introduced by the current thesis' Supervisors, or by the other interviewees. The details on selecting the potential interviewees to be approached is discussed later in this section.
- A recruitment email was initially sent to the potential interviewees. In this email, the individual was asked to participate in a 60-90 minute interview on topics related to the Waterloo region water management systems.
- After and if the individual accepted to take part in the interview, a letter of information and a consent form was sent to the interviewee to read and sign before the meeting. The letter of information includes a little information about the study, and the processes to give the individual assurance that the process and communicated information would be handled in accordance with the University research ethics guidelines.
- The interviews took place either in person, or through phone calls. In total, six (6) interviews took place.
- A set of questions were prepared for these meetings. The prepared questions were used as a broader guideline to discuss different aspects of the water management system. Issues

such as relevant stakeholders, existing and potential conflicts among the system's stakeholders, or external variables affecting the system were some topics covered in the interviews.

- After each interview, an appreciation email was sent to the interviewee to thank the interviewee for their participation in the research project.
- Each interview was then transcribed, and the material was incorporated into different sections of the thesis.

All forms related to the interviews are provided in Appendix A.

3.3.2.2. Interview Questions

As mentioned previously, the interviews with the main decisionmakers' representatives were based on a set of questions, which are provided in Appendix B. However, a semi-structured framework was used for the interviews, meaning that based on the interviewees' answers, the interview took different directions.

3.3.2.3. Identifying Interviewees

The interviews took place after secondary data collection, and before finalizing modelling and analysis of the results. The potential interviewees were identified and asked to take part in the research project based on secondary data collection, Supervisors' suggestions, and other interviewees' opinions.

Attempts were made to get in contact with different types of stakeholders, to achieve some diversity and to reduce the impact of any biased perspectives in gathering and categorizing the data. Overall, six (6) individuals were interviewed in 3 months. From these six people, two were high level executives of the Region of Waterloo, two were from the City of Waterloo, and the other two were researchers at the University of Waterloo. Three of these six individuals were interviewed multiple times and were in frequent communication with the author throughout the data collection and analysis phases of this thesis. In addition to these six individuals, insightful discussions with more than 20 people have contributed to the investigation and interpretation of the conflicts discussed in this thesis.

Since this thesis is focused on conflicts among water management system's stakeholders, some discussed topics in the interviews were of a sensitive nature. For example, water is distributed and sold by Waterloo Municipalities to consumers, however, before it is handed over to the municipalities, it has to be extracted, treated, and distributed by the Region of Waterloo. Because of this situation, the municipalities might not be that willing to support water conservation initiatives, since firstly, they are not in charge of finding water sources, and secondly, the more they sell, the more money they make. This issue was discussed in one of the interviews. However, naming the interviewee might risk his/her position. For this reason, the six interviewees and also, the other 20 contributors' identities are not specifically referenced throughout the thesis.

Chapter 4 GMCR Cases and Results

To better introduce GMCR method's processes and get a better sense of the Great Lakes water management system's conflicts, two cases are analyzed in this chapter using GMCR, however, the complete external analysis and scenario planning procedures are not conducted here. A full analysis of a relevant case including external and scenario analyses is presented in the 5th Chapter.

4.1. Case I: Great Lakes Water Extraction Permissions

The first analyzed conflict in the thesis is the conflict over Great Lakes water extraction permissions. For the sake of introducing the Graph Model for Conflict Resolution (GMCR) method (Fang et al.,1993; Kilgour et al., 1987), the GMCRII decision support system (Fang et al., 2003a; Fang et al., 2003b; Hipel et al., 1997), and to develop a simpler and more sensible model, only two decisionmakers (The Great Lakes Protectors and The Great Lakes Water Seekers) are focused on as the main decisionmakers of the conflict. In a sense, these are abstractions that serve to conceptually represent real classes of decisionmakers to explore and demonstrate key concepts developed as part of this thesis.

The Protectors try to reduce water demand and prevent everyone else outside the watershed from accessing the Great Lakes as much as possible. They not only have the authority over permission issuance, but also oversee water extraction operations should permissions be issued. However, Water Seekers are the category of stakeholders which seek access to the Great Lakes water source. They require enormous amounts of water to run their businesses and thus, search for water sources either from the Great Lakes, or from alternative sources such as wells or desalination. This information is determined by collecting data from various sources regarding previous and current statuses of these decisionmakers.

4.1.1. Causal Loop Diagram

The causal loop diagram for the current conflict is provided in Figure 4.1.

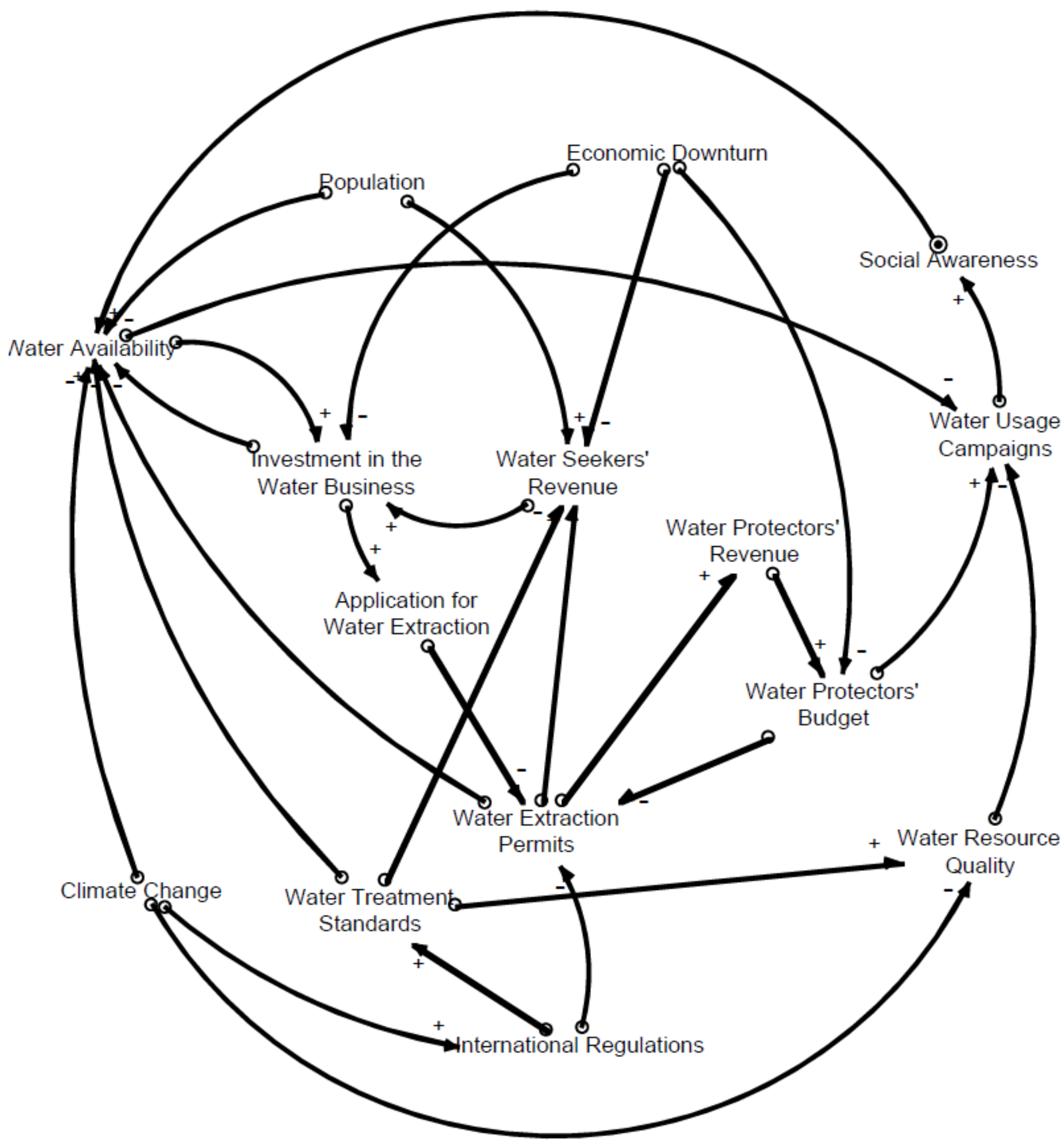

Figure 4-1. Case I: Initial Causal Loop Diagram

For example, a negative feedback loop in the system starts with increased water extraction permits being issued by authorities (i.e. Water Protectors). This increases Water Seekers' revenues since they would expand their businesses based on the new water extraction permits. This would in turn, pour investments into the businesses which require water permits. When more investment is initiated, more applications would be submitted to benefit from the permit issuance process. However, the applications coming in, gradually decrease the permit issuance rate.

4.1.2. Decisionmakers' Options

After initially investigating the situation through the system's causal loop diagram, the possible options of each decisionmaker are determined (Table 4.13). All GMCRII phases for this set of analysis are shown in Appendix C. We have focused on four options in total, two for each decisionmaker.

Table 4.1 Case I Decisionmakers and Their Options

The Great Lakes Protectors	1	Issue Permissions for Water Extraction
	2	Allow for Exceptions Under Strict Limitations
The Great Lakes Water Seekers	3	Seek Access to the Great Lakes Water Resource
	4	Seek Alternative Water Supplies (Well Water Treatment, Desalination, Rain Barrels, and etc.)

The Protectors consider two options. The first is to issue more permissions for water extraction to any stakeholder such as cities and regions outside of the Great Lakes watershed, or different heavy water consumers. Another option for the Protectors would be to impose tight restrictions but allow some exceptions regarding water extraction from the Great Lakes. For example, in most situations where strict limitations exist, the decisionmaker which extracts water must not only release the used water back into the Great Lakes, but also treat it before doing so.

An option for the Great Lakes Water Seekers, is to seek access to the Great Lakes through the regulators. This is important, since these decisionmakers require this permission to be flexible regarding their chosen water supply strategy. However, they can also seek alternative approaches to supply their required water. They can treat and use well or surface waters. In some cases, although more costly, they can also move towards more technologically advanced methods such as desalination. The Region of Waterloo suggested rain barrels to its clients as a method to satisfy their water shortages. These alternatives are a way of maintaining continuous and reliable sources of water for these water dependent organizations.

Each of the four options can be chosen or not by the decisionmakers. The combinations of decisionmakers' decisions (chosen options) develop different states. Therefore, the four options in the current conflict, produce sixteen (16) states which represent the combinations of the options that might occur (Table 4.2). Each state refers to a combination of decisions that could be chosen by the decisionmakers. In the below table, "N" means that the option is not chosen by the decisionmaker. And "Y" means that the option has been chosen by the decisionmaker.

Table 4.2 Case I States

Options \ States	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N
2	N	N	Y	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
3	N	N	N	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N	Y
4	N	N	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y

As an example of the states, State 1 is a condition in which none of the mentioned options is chosen by the two decisionmakers. This means that the Protectors will not issue more permits. Moreover, the Protectors do not allow any exceptions for water extraction. The Water Seekers would also not seek access to the Great Lakes. Moreover, they would be satisfied with their current supplies, meaning that they would not seek alternative methods for increasing their water supply. Another example is State 16 (the current situation which is titled as the status quo and is shaded in Table 4.2), where the Protectors would only issue permits for rare exceptions, and impose many more restrictions on water withdrawal and water treatment standards and other water extraction related issues (e.g. the city of Waukesha which was mentioned in the introduction). However, Water Seekers would actively seek permission to extract water from the Great Lakes in spite of tight restrictions. They would also seek alternatives to guarantee their water supply from other resources. This means that the Water Seekers would adapt themselves to the challenging restrictions imposed by the Protectors to expand their water resource reach.

4.1.3. Feasible and Infeasible States

In the next step, after identifying the decisionmakers and their options, states that are identified as impossible to occur based on logical interpretations of the state presented by the particular combination of options are called infeasible states and removed from the model. In other words, combinations of options that are mutually exclusive create logically infeasible outcomes (Hipel and Fang, 2021).

From the 16 possible states (noted in Table 4.2), four states are deemed infeasible (states 6, 7, 13, and 15). This is because in these states, the Protectors choose option number one (to issue many more permits) and option number two (to impose much more restrictions on heavy water consumers regarding water extraction, water treatment, and other issues) at the same time, however, this is not feasible in the real world. Thus, these states are removed from the analysis.

Table 4.3 Case I Feasible and Infeasible States (shaded cells represent infeasible states)

Options \ States	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N
2	N	N	Y	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
3	N	N	N	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N	Y
4	N	N	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y

All feasible states are renumbered as shown in Table 4.3. The status quo is State 12 which is shaded in Table 4.4

Table 4.4 Case I Feasible States

Options \ States	1	2	3	4	5	6	7	8	9	10	11	12
1	N	Y	N	N	Y	N	N	Y	N	N	Y	N
2	N	N	Y	N	N	Y	N	N	Y	N	N	Y
3	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y
4	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y

4.1.4. Decisionmakers' Preferences

Decisionmaker's preferences are ranked from the most preferred to the least preferred state for each decisionmaker (Table 4.4 and Table 4.5). Table 4.4 shows that the Protectors prefer state number 7, as they do not have to permit any new water extractions and they also do not approve of any exceptions. Moreover, in this state, the Water Seekers are interested in alternative water sources instead of seeking access to the Great Lakes. The Protector's least preferred state is State 5, in which they issue more permissions to anyone who applies. Moreover, the Water Seekers are interested in seeking access to the Great Lakes, but not any alternative water sources. Overall, the Protectors are in favor of not permitting more water extractions to more decisionmakers, with more restrictions on possible exceptions.

Table 4.5 Protectors' Preferences

Options \ States	7	1	10	4	9	3	12	6	8	2	11	5
1	N	N	N	N	N	N	N	N	Y	Y	Y	Y
2	N	N	N	N	Y	Y	Y	Y	N	N	N	N
3	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y
4	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N

Table 4.5 shows preferences for the Water Seekers (in the "Preference Vector" row). Water Seeker's most preferred state is State 11as there is permission for more water extraction, and the Water Seekers are interested in accessing the Great Lakes and also other alternatives. The least preferred state for them would be State 1 in which there are no water extraction permissions and no exceptions. And also, they are stuck with the current water sources, not seeking access to any additional water sources.

Table 4.6 Water Seekers' Preferences

Options \ States	11	5	8	2	12	6	9	3	10	7	4	1
1	Y	Y	Y	Y	N	N	N	N	N	N	N	N
2	N	N	N	N	Y	Y	Y	Y	N	N	N	N
3	Y	Y	N	N	Y	Y	N	N	Y	N	Y	N
4	Y	N	Y	N	Y	N	Y	N	Y	Y	N	N

As can be seen from the above table, States 11, 5, 8, and 2 stand higher in the Water Seeker's preference table than the other eight states. This is because in all of these states, the Protectors have already chosen to issue permissions for water extractions (Option 1 is selected), making Water Seekers position much more relaxed. The Water Seekers can extract as much water as they require (Option 3 is selected; States 11 and 5), without the Protectors fiercely opposing them. And in the case that the Water Seeker's capacity is complete and they do not require additional amounts of water, they can simply stop extracting more water (Option 3 is not selected; States 8 and 2).

The next four preferences for Water Seekers are States 12, 6, 9, and 3, in which Option 2 is selected by the Protectors, instead of Option 1. In these states, the Protectors are not openly issuing approvals for all extraction applications, but only allow for limited and strictly regulated exceptions to be considered. This might not be an ideal situation for Water Seekers, however, it is still much better than not having the chance of extracting water (States 10, 7, 4, & 1).

4.1.5. Stability Analysis

In the next step of the graph model technique, stability analysis using logical rules (i.e. solution concepts; Table 3.1) that describe decisionmakers' strategic interactions are applied to every outcome in the conflict model. The result is shown in a table, called the "Tableau Form" (Fraser and Hipel, 1979; Fraser and Hipel, 1984) (Table 4.7).

Table 4.7 Case I Preferences and Stability Analysis

The Great Lakes Protectors												
Overall Stability	X	X	E	X	X	X	X	X	X	X	X	X
Decisionmaker Stability	R	R	R	R	U	U	U	U	U	U	U	U
Preference Vector	7	1	10	4	9	3	12	6	8	2	11	5
UIs					7	1	10	4	7	1	10	4
									9	3	12	6
The Great Lakes Water Seekers												
Decisionmaker Stability	R	S	S	S	R	S	S	S	R	U	U	U
Preference Vector	11	5	8	2	12	6	9	3	10	7	4	1
UIs		11	11	11		12	12	12		10	10	10
			5	5			6	9			7	7
				8				6				4

* E: Equilibrium, R: Rational, S: Sequentially sanctioned, U: Unstable for a particular decisionmaker, X: Unstable for at least one decisionmaker, UIs: Unilateral Improvements.

For example, based on the Nash Stability solution concept (R), the most preferred state for each decisionmaker is always rational. This is because rationally, the decisionmaker would not move from it to a less preferred state.

States indicated by "U" in Table 4.7 represent unstable states for a particular decisionmaker. These states are considered unstable since the decisionmaker has the opportunity to unilaterally improve to another more preferred state instead of remaining in that less preferred status.

For example, the Protectors change their option selections from State 9 (N, Y, N, Y) to State 7 (N, N, N, Y). Through this move, they unilaterally improve their status from a less preferred state (9) to a more preferred state (7), without any required interventions from the Water Seekers (Table 4.8).

Table 4.8. Example of an Unstable State

State	9		7		10
Protectors	N	UI →	N		N
	Y		N		N
Water Seekers	N		N	UI →	Y
	Y		Y		Y

Then, the Water Seekers would unilaterally improve (without any actions required from the Protectors) from State 7 (N, N, N, Y) to State 10 (N, N, Y, Y) to enhance their status in the conflict. However, going through the preference table for Protectors, it is known that State 10 is more preferred than State 9 for Protectors. So, the Protectors initial unilateral improvement from State 9 (to State 7), results in the conflict to end up in State 10, which is more preferred for the Protectors. Thus, State 9 is considered to be an unstable state (U) for the Protectors.

In some cases, although the decisionmaker's true intention is to improve to a better state, the consequence of its unilateral improvement may not be in its favor since it may give the opportunity to the other decisionmakers to unilaterally improve despite its disagreement. As mentioned before in Table 3.1, under the solution concepts, these initial states are called sequentially sanctioned (Hipel et al., 1993) and are shown by "S" in Table 4.7.

As an example, the Water Seekers can unilaterally improve from State 6 (N, Y, Y, N) to State 12 (N, Y, Y, Y). Then, the Protectors would unilaterally improve from State 12 to State 10, since it is a more preferred state for them. But State 10 is a less preferred state than State 6 for Water Seekers. In these situations, it is rational for the decisionmakers to stay at their current state rather than unilaterally improve to begin with. Therefore, State 6 is considered to be sequentially sanctioned for Water Seekers (Table 4.9).

Table 4.9 Example of a Sequentially Sanctioned State

State	6		12		10
Protectors	N Y		N Y	UI →	N N
Water Seekers	Y N	UI →	Y Y		Y Y

After identifying the stability of individual states for each decisionmaker, equilibrium states which are stable states for all the decisionmakers are identified. These states are shown by "E" in Table 4.7 and are states in which there is overall stability among the decisionmakers. This is a situation where the decisionmakers have transitioned to other states a few times, and they have reached to an equilibrium which is rational for all decisionmakers, meaning that everyone is stable and cannot unilaterally improve to another state. The remaining states that are indicated by "X" represent states that are unstable for at least one decisionmaker.

Having State 10 is stable for both the Protectors and the Water Seekers while the other states are stable under some but not all solution concepts. Therefore, State 10 is the equilibrium state in this model. In this state, the Protectors would not be issuing more permissions to additional decisionmakers to extract water from the Great Lakes. They would also not approve of any exceptions for any applications regarding extracting water from the vulnerable water source. The Water Seekers however, would be actively seeking access not only to the Great Lakes, but also to other possible alternatives they could access.

State 10 to end up as an equilibrium state in this conflict, is also reflected in reality. An example, also briefly mentioned in the Literature Review Chapter, is Wisconsin State's Waukesha city, which is very close to, but outside Great Lakes watershed. Radium contamination of this City's water sources, has resulted in a shortage of fresh water in Waukesha, forcing the City to desperately seek water from the Great Lakes since 2010 (Mehta 2016).

Approval was issued in 2016 by each of the Great Lakes states to pipe 8.2 million gallons of Lake Michigan water a day from Milwaukee and to return the treated wastewater to Lake Michigan through the Root River. However, controversy started growing as cities such as Thunder Bay and New Berlin objected to the approval, and this started a long period of debates on whether this and similar exceptions in water extraction should or should not be approved (Kaeding, 2020; Simroth, 2020).

The Waukesha city experience demonstrates the high level of resistance in the Great Lakes' Water Protectors to approve water extractions outside of the Great Lakes' watersheds. The topic has been under controversial debate since 2010, with very slow progress towards resolution and final construction of the pipeline. Even as recent as August 2020 (after 10 years), authorities state that "*nearly* all of the state and federal permits have been issued", which is a reflection of the many objections of some influential stakeholders (Simroth, 2020). Although issuing water extraction exceptions have been considered in agreements among Great Lakes' stakeholders (Kane, 2017; Sheikh and Brougher, 2008), what has happened in reality reflects a situation in which permission issuance and water diversion simply does not occur. The very few diversions to outside of the Great Lakes watershed that have been happening since before the agreements came to existence (e.g. the Chicago diversion which has been implemented since 1848), have been seriously cut back to decrease the amount of diversions from the Great Lakes to less than one-third of the original diversion rate (Quinn and Edstrom, 2000).

4.1.6. The Integrated Graph Model

To illustrate a better perspective of the studied case, the integrated graph model of the conflict is developed by using Gephi (an open-source network analysis and visualization software package) (Figure 4.2).

The graph model helps in illustrating a better sense of decisionmakers' movements through the feasible states. The numbers shown at the nodes refer to the feasible states presented before. The arcs represent state transitions for each decisionmakers' unilateral moves from one state to another, which occur when a particular decisionmaker makes a selection from the options it controls.

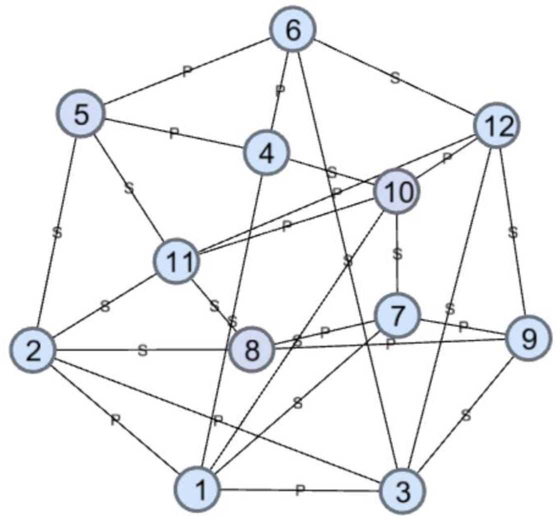

Figure 4-2. Integrated Graph Form * P: Water Protectors, S: Water Seekers Note: The relations between the arcs are all bidirectional.

Although Figure 4.2 shows all movements (including improvements and disimprovements) for all decisionmakers; in reality, when transitioning from one node to the other, the decisionmakers consider their preferences and tend to move to more favorable states (i.e. unilateral improvements). Overall, the graph model gives a better sense of decisionmakers' movements toward their preferred feasible states.

4.2. Case II: Drinking Water Conflicts over Grand River

Grand River is a major source of water pouring into Lake Erie. Although more than 60 percent of Grand River's water is consumed through municipal usages, the rest of the water is used by other decisionmakers. Studying the below pie chart (Figure 4.3), helps in better understanding Grand River watershed's water conflicts, especially when it is experiencing extended periods of lower rainfall and high temperatures which lowers surface water levels, aggravating water disputes. For example, water bottling companies have been criticized for their drinking water extraction from the Grand River. Similarly, other stakeholders such as manufacturing industries and agricultural users are getting into more and more conflicts with the Regions, Cities and NGOs surrounding the Grand River.

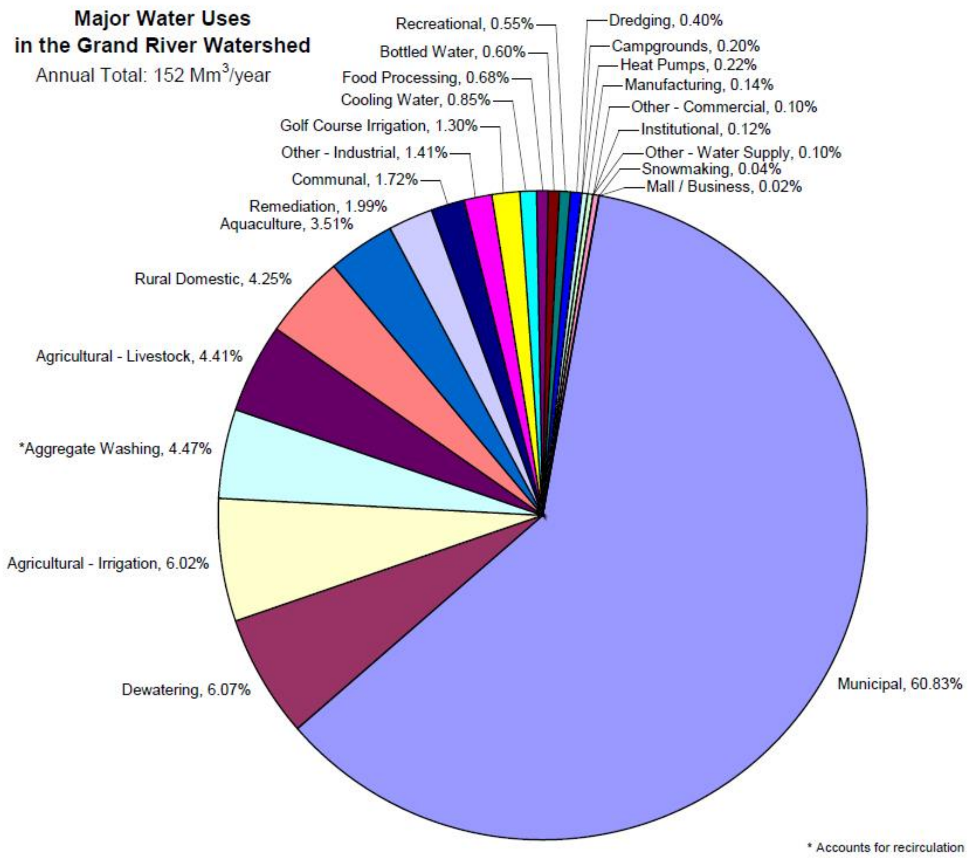

Figure 4.3. Major Water Uses in the Grand River Watershed (Etienne, 2014)

The worsening of these water conflicts is taken seriously by decisionmakers in the watershed to the extent that the Region of Waterloo started working on a Master Plan which proposed drawing a pipeline from Great Lakes (Lake Huron or Lake Erie) as an alternative to other water sources already in use (Gombos, 2014). Although implementing this alternative has been deferred from the year 2035 to beyond 2050, it shows that the shared Grand River water source (Figure 4.4: Map of the Grand River Watershed) is vulnerable and requires intricate handling to remain a sustainable resource in the region.

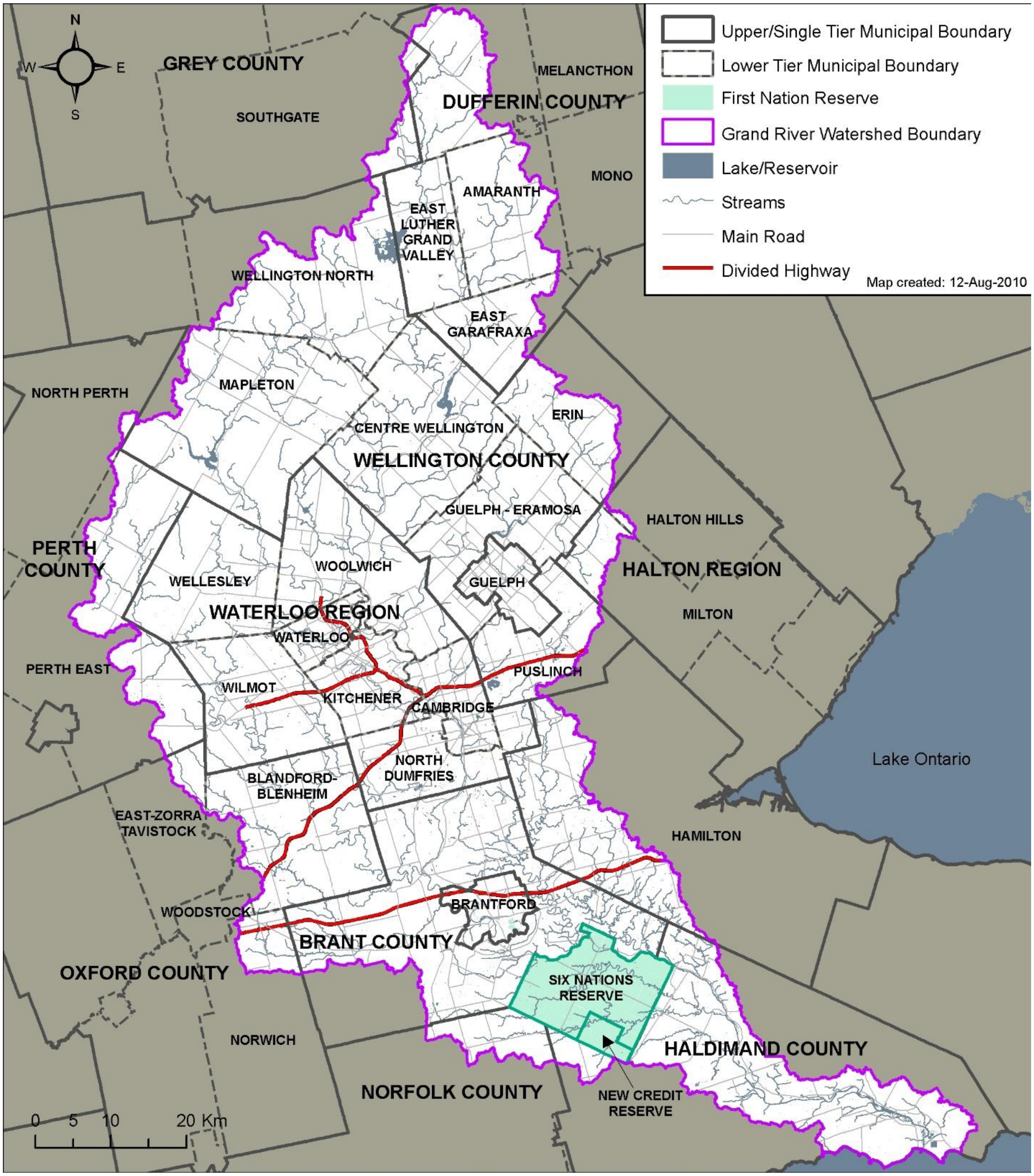

Figure 4.4. Map of the Grand River Watershed (WaterCanada, 2015)

In sum, powerful and ambitious water bottling companies such as Nestle, the issuance of drinking water extraction permissions from Ontario's Ministry of the Environment, and heavy water-use in other industries (e.g. in Ontario farms for agricultural irrigation), and broader factors such as climate change, are variables which increase the rate of exhaustion of water sources in Ontario. Multiple governmental offices and NGOs which initiate various events, conferences, and other initiatives (e.g. the AquaHacking 2017 Challenge at University of Waterloo which attempts to develop functional, marketable ideas to solve Lake Erie's water concerns), are decisionmakers in opposition with the previously mentioned stakeholders (University of Waterloo, 2020).

Although water bottling companies such as Nestle try to encourage the use of bottled water, decisionmakers such as the Waterloo Region are promoting tap water, arguing that it is safe, since tap water undergoes more than 120 different water quality tests at Waterloo Region, contrary to bottled waters which are not mandated to meet the requirements for mineral or spring water set by the Canadian Food Inspection Agency. It is also argued that tap water is much more environment-friendly since they do not produce any bottles/plastic waste, and also, they do not impose vehicle transportation costs and pollution related to transporting the product (water bottles) from where they have been bottled to retailers and final consumers. This decreases gas emissions from the transportation vehicles. Moreover, Municipalities and Regions in the Grand River watershed, advertise that tap water is cheaper. It costs the customer much less than one cent to a liter of tap water in the Region of Waterloo, but $2 per liter to buy water in the bottled form. Finally, it is argued that tap water is much more accessible and convenient compared to bottled water accessibility (Region of Waterloo, 2020b).

The conflict between the two decisionmakers runs deep and each of the sides are taking actions to oppose the other decisionmaker in this escalating conflict. For example, the Region of Waterloo Public Health supports private well owners through partnering with the Residential

Energy Efficiency Project (REEP) and The Grand River Conservation Authority (GRCA). This support is in the form of free well assessments (bacteriological testing) to help well owners keep their drinking water safe and healthy, without the need of buying bottled water from commercial businesses (Government of Canada, 2018).

In another symbolic gesture against bottled water companies, Waterloo Region banned single use bottled water sales in public facilities in 2008. In line with the aforementioned banning, the City of Waterloo is encouraging private businesses and other types of institutions to be water-bottle friendly establishments (through the Blue Water program). This means that the institution would be openly inviting to everyone to come in and fill up their reusable water bottles with free tap water inside their facilities. The Water Wagon mobile drinking project is also another approach that the Region of Waterloo (like other Municipalities such as the City of Guelph) is taking to promote drinking water from municipal tap water over bottled water. Moreover, the Region of Waterloo subsidizes on the cost of 200-litre rain barrels to promote their usage in an attempt to save on water costs and decrease overall water demand whether it be drinking or other water usages (Region of Waterloo, 2020b).

Other than the Waterloo Region, there are other types of institutions in Waterloo region that are also actively trying to decrease bottled water consumption through various methods. For example, an initiative at Wilfrid Laurier University, although unsuccessful, tried to stop the sales of water bottles on its campuses through the promotion of easily accessible filtered water-fill stations and other alternatives (Wilfrid Laurier University, 2020).

These were some examples of disputes among opposing decisionmakers on water extraction or conservation in the Grand River watershed (which itself is located within the Lake Erie watershed). To showcase the complexity of water management dynamics in the Great Lakes' watersheds, and to better introduce the GMCR method, the conflict between Nestle and the City of Guelph is discussed below. The City of Guelph has authority over water extraction permission issuance from the Grand River watershed. However, it is also responsible for conserving and maintaining water availability for the community. This added to business owners' pressures to extract more water from the watershed, results in disputes over the topic.

4.2.1. Causal Loop Diagram

The below causal loops are developed for the two major decisionmakers in this section's conflict (Figure 4.5 and Figure 4.6). Although the City of Guelph has control over decisions such as issuing more permits for water extraction, it is also affected by external variables such as climate change and population growth. The more climate change effects become severe, the stricter the City will be in issuing new permits. And less permits mean less pressure on available water resources. Each of the variables below have a direct or indirect effect on other variables and on the system as whole (the variables with the grey colour are external factors affecting the system).

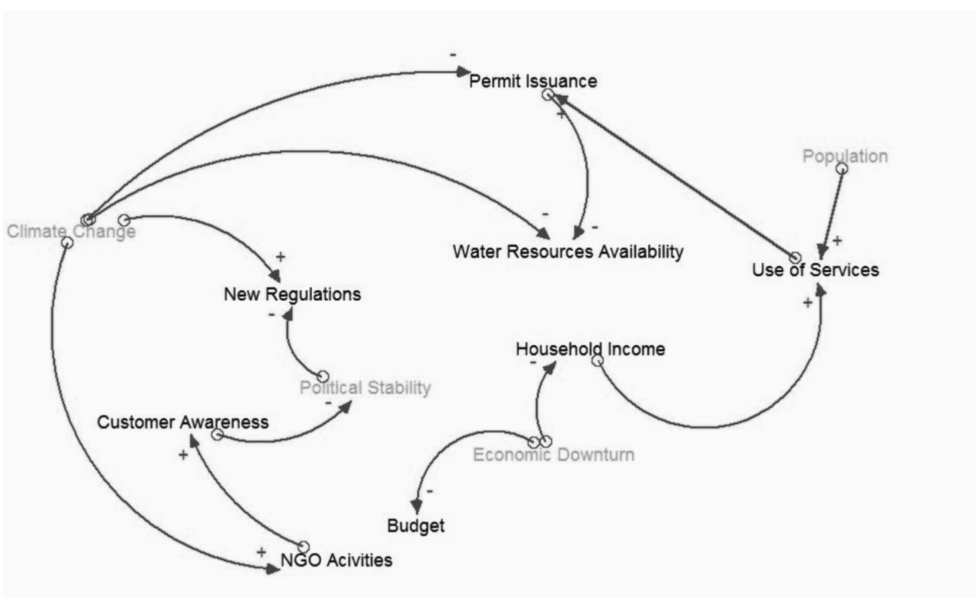

Figure 4.5. City of Guelph's System Dynamic Status Quo

Nestle's causal loop (Figure 4.6) is more focused on reducing its costs, increasing its revenues, satisfying its customers, and expanding its business. And again, external variables such as climate change, population, competition, and new regulations affect this status quo. For example, more restricting regulations limits expansion efforts by Nestle. Or more population means more revenue for Nestle.

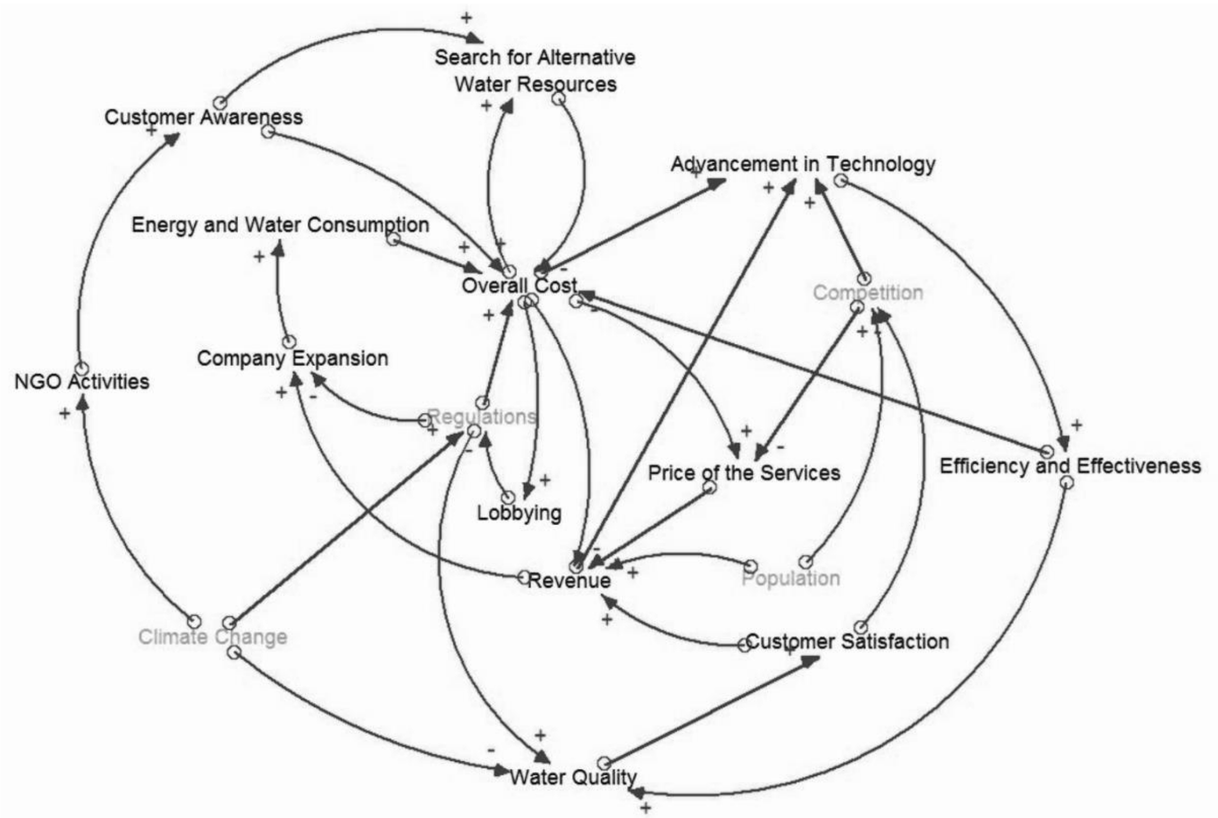

Figure 4.6. Nestle's System Dynamic Status Quo

4.2.2. Decisionmakers' Options

For the sake of the current case study, and to develop a simpler and more sensible model, only two decisionmakers (City of Guelph and Nestle) and specific variables are focused on as the main decisionmakers and variables of the conflict.

The possible options of each decisionmaker are determined. Four options in total for the decisionmakers are identified (two for each decisionmaker) (Table 4.10). These options are developed based on various sources (e.g. articles, interviews, and etc.). The four developed options represent the main decisions that each decisionmaker might make in the current conflict.

Table 4.10: Case II Decisionmakers and Their Options

City Options	1	Permit for Privatization
	2	Tight Restrictions
Nestle Options	3	Water Export
	4	Distribute in National Level

It seems that the City is considering two options for itself. The first is to issue more water extraction permits for different heavy water consumers including Nestle. In this situation, these consumers are given permits to withdraw more water from the available water resources in the region. Another option for the City would be to impose tight restrictions for heavy water consumers regarding not only water extraction, but also other issues such as water treatment after withdrawing water from the water resources and also before releasing the used water back into the water resources.

An option for Nestle, as a water bottling company is to export the water it extracts from the region’s water resources. Exporting water from Canada, as a major freshwater resource, to other less resourceful countries (e.g. US), is an important strategy that Nestle is looking into in the long term. The other option that Nestle might choose, is to sell its bottled water in Canada more than before.

State 1 is a condition in which none of the mentioned options is chosen by the two decisionmakers (Table 4.11). This means that the City does not issue more permits, other than the ones that are already issued. Moreover, the City does not impose more restrictions. Nestle would also do what it has been doing. In other words, none of the two decisionmakers would change their strategies in this state. As another example, in state 16, the City would impose much more restrictions on water withdrawal and water treatment standards and other water extraction related issues. However, Nestle decides to export water and also, sell nationally, in spite of these tight restrictions. This means that Nestle would adapt itself to the challenging restrictions imposed by the City to expand its business nationally and internationally.

The status quo (State 11) is shaded in the below table (Table 4.11). In this state, the City does not issue more permits, other than the ones that are already issued. Also, no more restrictions are imposed by the City. Nestle exports water and sells nationally. In the below table, “N” means that the option is chosen by the decisionmaker. And “Y” means that the option is chosen by the decisionmaker.

Table 4.11: Case II States

States / Options	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N
2	N	N	Y	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
3	N	N	N	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N	Y
4	N	N	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y

4.2.3. Feasible and Infeasible States

From the 16 possible states in the current case, only 12 of them are feasible or acceptable (Table 4.12). For example, the City would not be able to choose option 1 (issuing more permits) and option 2 (imposing more restrictions on heavy water consumers regarding water extraction, water treatment, and other issues) at the same time. Thus, states that have these two options (have a "Y" in option 1 and option 2), are infeasible (cannot happen in the real world) and are removed from the analysis. These infeasible states are highlighted in the table below.

Table 4.12: Distinguishing Feasible and Infeasible States (shaded cells represent infeasible states)

States / Options	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	N	Y	N	N	N	Y	Y	Y	Y	N	N	N	Y	Y	Y	N
2	N	N	Y	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y
3	N	N	N	Y	N	Y	N	Y	N	Y	Y	N	Y	Y	N	Y
4	N	N	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y

The feasible states are now ready to be analyzed (Table 4.13). The status quo (State 10) is shaded in this table.

Table 4.13: Feasible States

States / Options	1	2	3	4	5	6	7	8	9	10	11	12
1	N	Y	N	N	Y	N	N	Y	N	N	Y	N
2	N	N	Y	N	N	Y	N	N	Y	N	N	Y
3	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y
4	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y

4.2.4. Decisionmakers' Preferences

Now that the feasible states are developed, decisionmakers' preferences are ranked from the most preferred to the least preferred state for each decisionmaker. The below table shows preferences of the City of Guelph (Table 4.14). The City prefers not to issue more permits for heavy water consumers such as Nestle. It favors imposing restrictions to keep its control over the region's water resources. However, it also favors exportation of water to other countries. This brings money into the City's system, increasing its budget for other infrastructural activities.

Therefore, although the states numbered 3 and 1 are the most preferred states for City of Guelph, state number 6 is also favored by the City. In this state, Nestle is exporting the extracted water with a tight control over it by the City. The least preferred state for the City is when it issues more permits for heavy water consumers, with no more restrictions. This is accompanied by water exportation and national distribution by Nestle.

Table 4.14: City of Guelph Preferences (State Ranking)

States / Options	3	1	6	9	12	2	4	7	10	5	8	11
1	N	N	N	N	N	Y	N	N	N	Y	Y	Y
2	Y	N	Y	Y	Y	N	N	N	N	N	N	N
3	N	N	Y	N	Y	N	Y	N	Y	Y	N	Y
4	N	N	N	Y	Y	N	N	Y	Y	N	Y	Y

The below table (Table 4.15) shows preferences of Nestle. As it can be seen, Nestle prefers state number 11 over other states. State 11 is a situation in which the City issues more permits for water extraction. And Nestle, taking advantage of City's strategy, not only exports more water to other countries, but also sells its products nationally in Canada. This is regarded as the most preferred state for Nestle since in this state, Nestle is using all of its capacity in expanding its business across the globe and Canada.

The next preferred state for Nestle is State 5. In this condition, permits for water withdrawal are issued more by the City and Nestle focuses immensely on exporting bottled water to other countries. This helps Nestle guarantee market shares worldwide. This is a more preferred state than state 8 in which the permits are issued by the City, but Nestle only expands nationally. Overall, Nestle is in favor of a situation in which it has City's approval to expand, with less restrictions on extraction and treatment standards. Also, it favors exporting over solely working nationally in Canada. Based on the provided statement above, the least preferred state for Nestle is when there are many restrictions imposed by the City and Nestle changes nothing in its current strategy.

Table 4.15: Nestle Preferences (State Ranking)

States / Options	11	5	8	10	2	4	7	12	6	9	1	3
1	Y	Y	Y	N	Y	N	N	N	N	N	N	N
2	N	N	N	N	N	N	N	Y	Y	Y	N	Y
3	Y	Y	N	Y	N	Y	N	Y	Y	N	N	N
4	Y	N	Y	Y	N	N	Y	Y	N	Y	N	N

4.2.5. Stability Analysis

In the next step of the graph model technique, stability analysis using previously introduced solution concepts (Table 3.1) that describe decisionmakers' strategic interactions are applied to every outcome in the conflict model.

Table 4.16: Case II Decisionmakers' Preferences and Stability Analysis

						City of Guelph						
Overall Stability	X	X	X	X	E	X	X	X	X	X	X	X
Decisionmaker Stability	R	S	R	R	R	U	U	U	U	U	U	U
Preference Vector	3	1	6	9	12	2	4	7	10	5	8	11
UIs		3				3	6	9	12	6	9	12
						1			9	4	7	10
						Nestle						
Decisionmaker Stability	R	S	S	R	U	S	S	R	U	U	U	U
Preference Vector	11	5	8	10	2	4	7	12	6	9	1	3
UIs		11	11		11	10	10	12	12	12	10	12
			5		5		4			6	4	6
					8						7	9

* E: Equilibrium, R: Rational, S: Sequentially sanctioned, U: Unstable for a particular decisionmaker, X: Unstable for at least one decisionmaker, UIs: Unilateral Improvements.

As can be seen in the Tableau Form (Fraser and Hipel, 1979; Fraser and Hipel, 1984) (Table 4.16), state 12 is the equilibrium state for this conflict. In this state, the City does not increase the number of permits for privatization. Moreover, it pushes for regulating the industry with increasingly tight restrictions. Nestle tries to adapt to these restrictions and starts exporting under the new regulations. It also increases its national distribution in Canada, under the new restrictions in an attempt to expand its business.

To understand why State 12 becomes the final equilibrium state in this conflict, a few unilateral improvements would be described. For example, consider a situation in which the conflict is in State 3, which is the most preferred state for the City of Guelph. In this situation, the City does not allow for more water extraction, and tight water extraction and treatment regulations also exist. In State 3, Nestle is neither exporting water, nor expanding nationally in Canada. However, since State 12 is more preferred than State 3 for Nestle, and that it can unilaterally improve to State 12 without the involvement of City of Guelph. Therefore, the conflict would not be stable in State 3, even though the City of Guelph prefers that it stays there. Also, if the conflict is in State 11, Nestle is exporting water internationally, and is also expanding its business nationally. And the City of Guelph lets Nestle do this, without limiting permission issuance. As mentioned before, this state (State 11) is the most preferred state for Nestle. However, in this situation, the City of Guelph can unilaterally improve to State 12, since this state is more preferred for the City of Guelph as compared to State 11. So, even if Nestle is not on board with the conflict transitioning from State 11 to State 12, this issue will happen because the City of Guelph can independently make the transition, even without Nestle's approval.

Similar to the two examples provided above, this trend of independent unilateral moves from both sides of the conflict happens in all the feasible states of this conflict. And in all scenarios, the conflict ends up in State 12, the equilibrium state.

This ending up of the conflict in State 12, is also reflected in reality. In the past years, Nestle has been exporting water from the Great Lakes watersheds in single use plastic bottles to be sold across Canada and other parts of North America. The Province of Ontario and the City of Guelph have come to defend Nestle's business in many circumstances (e.g. City of Guelph, 2020). However, the trend of the conflict shows that it is slowly transitioning towards State 12, in which the City of Guelph is being convinced by the community and the many NGOs opposing Nestle's water extraction operations, to reject further Nestle renewal applications.

NGOs have been fighting Nestle fiercely in the past few years. Some have continuously expressed their contention and concern about limited future availability of water for the community (Khan, 2020; Rubin, 2020), while others simply oppose the huge profit Nestle is making through extracting and exporting water from the watershed (Boucher, 2016; GuelphToday, 2018).

The relentless community pressures on the City to put a hold onto further water extraction approvals for water bottling companies such as Nestle, has proved to be working based on the City's statements, which show that authorities are also getting more and more conservative about issuing approval renewals. As an example, in the City's 2016 report regarding this matter (City of Guelph, 2016), it has been mentioned that "'there are limits to the available groundwater to satisfy Guelph's future water supply needs" (CBC, 2016), and "as such, future renewals of industrial water takings in the area should be weighed against the broader needs of the community, the potential risk that available supply may not meet future demand and that the continued water takings may not be sustainable without proper management of the resource" (Hallett, 2016). These statements, after all the ongoing demands from the community pushing for a change in the permission issuance regulations, is a clear indicator that the conflict between water bottling companies such as Nestle and the authorities will soon be transitioning to State 12, in which tighter regulations will be announced in regards to issuing water extraction permissions from the Great Lakes watersheds.

Chapter 5 Application of the Proposed Framework

Now that we have gone through the GMCR method through relevant examples, and also, gained knowledge of the various conflicts surrounding water resources in the Great Lakes regions, we can proceed with a complete application of the previously proposed framework in this thesis (Section 3.2. Methodology used for this Thesis). A central conflict over time in the Great Lakes watershed has been around algae in Lake Erie. Evolving through the decades, this conflict is analyzed through two full cycles of the methodology outlined in Figure 3.4, and insights in potential future related conflict avoidance or resolution are offered based on this analysis.

5.1. Rising Phosphorous Levels in Lake Erie

Lake Erie has a surface area of 25,700 square kilometres, and an average depth of only 19 metres (Thames River Phosphorus Reduction Collaborative, 2018). Among the Great Lakes, Lake Erie is the shallowest in depth, smallest by volume, and warmest in temperature. It also has the most densely populated watershed.

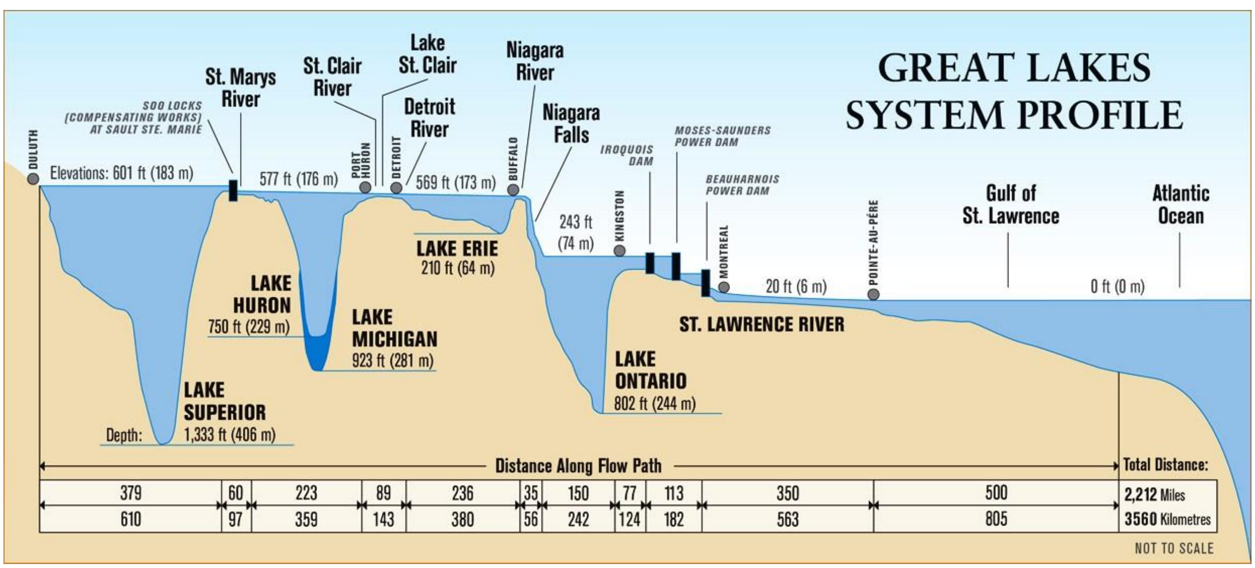

Figure 5.1. Great Lakes System Profile (Michigan Sea Grant, 2018)

The Canadian side of Lake Erie supports 2.68 million people, 53 per cent of them in eight urban areas (i.e., populations over 50,000) and the rest in smaller towns and rural areas. Agricultural production accounts for about three-quarters (75%) of the land use on the Canadian side of the basin. Urban centres, settlements and roads make up 12 per cent of land area, with natural areas accounting for another 13 per cent (Government of Canada, 2018).

Lake Erie not only is a source of drinking water for municipal residents, but also brings various commercial and recreational opportunities for the region. It is the most biologically diverse and productive of the Great Lakes because of its shallow depth and warm temperatures. It is home to more than 130 fish species, some of which (like Walleye and Yellow Perch) support large commercial and recreational fisheries. It is an important food, spawning, nursery and refuge habitat for aquatic and terrestrial species) as well (Government of Canada, 2018).

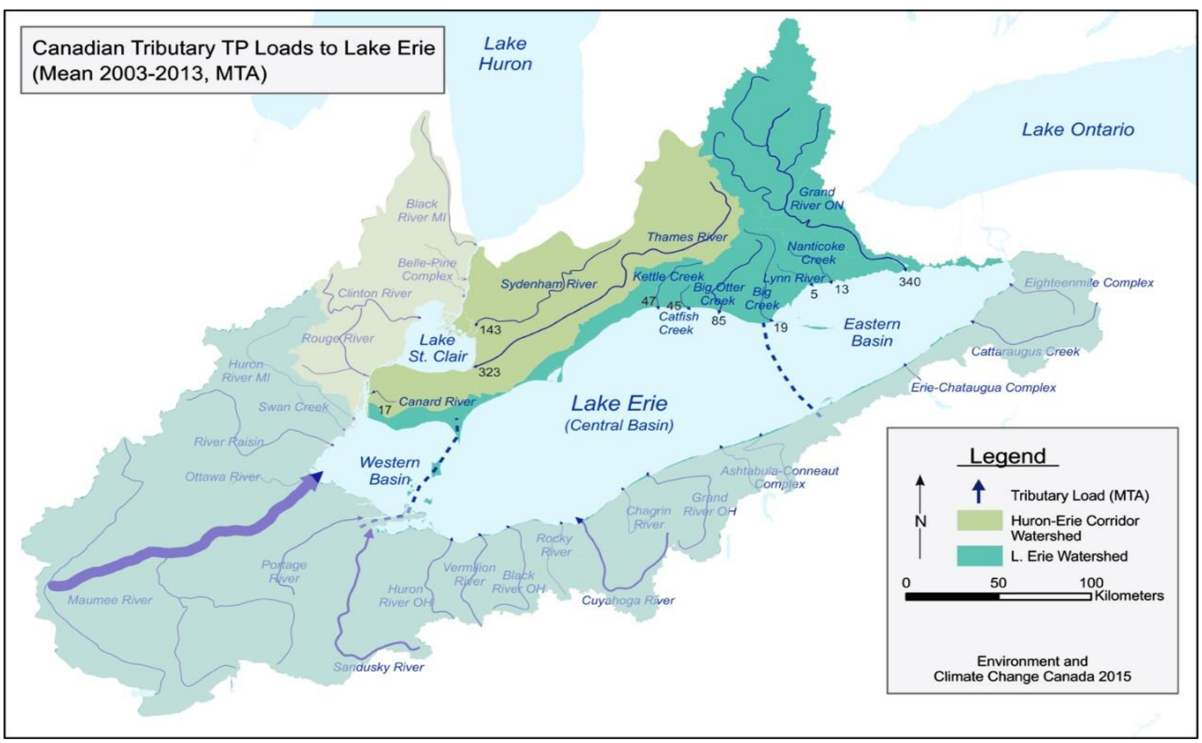

Figure 5.2. Rivers Pouring into the Lake Erie (Environment and Climate Change Canada, 2017)

A lot of water sources eventually pour into Lake Erie such as Thames River, which flows into Lake St. Clair, the Grand River, which flows into the eastern basin, the Sydenham River, which discharges to Lake St. Clair, and Kettle and Big Otter Creeks, which discharge to the central basin (Figure 5.2). Discharges from Lake Superior, Lake Michigan, and Lake Huron also drain into Lake Erie through the Detroit River (Government of Canada, 2018).

Lake Erie has been facing serious challenges. For example, Algae (or Algal) blooms and zones of low oxygen have been increasing in Lake Erie over the past decade (TidesCanada, 2015). The root of the problem is excess phosphorus entering Lake Erie from multiple sources.

Some of these sources can be specifically located, since they are diffused from a certain point. These are called point source phosphorous pollution. They discharge from sources such as industrial treatment plants, livestock farms, and municipal sewage treatment outlets. The other type of phosphorus pollutions originates from non-point sources. Rainfall and snowmelt start moving over and through grounds, picking up phosphorous and other types of pollutants on the way. They finally pour into lakes and rivers, increasing pollutant levels in them. The phosphorous in non-point sources are usually picked up from agricultural land fertilizers, and runoffs from industrial and urban landscapes (e.g. faulty septic systems, pet waste, and lawn fertilization). When rainfalls or the melting snow are in the form of storm water, they carry much more pollutants into the rivers or lakes (EPA, 2020).

Physical characteristics and human activities in Lake Erie’s watershed make it the most reactive of the Great Lakes to weather changes and thus, phosphorus inputs (Shin, 2013). A lot of the pollution that gets into Lake Erie comes from rivers flowing into Lake Erie, including the Grand River on Ontario.

Excess phosphorous and in turn, increased algal blooms significantly increase water treatment costs, especially for municipal drinking water systems and industrial manufacturers, including food processing and bottled water companies. Moreover, algal blooms impose increased health care costs due to exposure to the pollutants. Also, the food web structure and ecosystem functioning are altered, negatively affecting recreational and commercial fisheries (Shin, 2013). All of these would reduce property values due to loss of recreational opportunities. Another consequence would be reduced tourism revenue due to beach closures.

All of this costs the Canadian Lake Erie basin economy at least $272 million annually. The economic loss to the commercial fishery as a result of these changes could exceed $100 million over the next 25 years. As another example of the financial consequences, the lack of water for just five days in mid-July, due to a shutdown of municipal water supply in an area, is enough to result in a loss of crops and $290 million in total revenue from local greenhouse operations (Government of Canada, 2018).

As a brief timeline, the problem was discovered as a serious risk to the health of the people and ecosystem in the 1960s. It was in 1968 in which phosphorus loadings reached a peak of approximately 28,000 tonnes per year (Government of Canada, 2018).

In the 1970s, Canada, Ontario and the U.S. invested billions of dollars in point source pollution control, especially wastewater treatment plant upgrades. In 1972, the International Joint Commission (IJC) established the Pollution from Land Use Activities Reference Group (PLUARG) to investigate the impact of land-based activities on pollutant loadings (International Joint Commission, 2020). It was in the 70s in which both US and Canadian governments initiated programs to decrease the high levels of phosphorous in Lake Erie. Interestingly, the phosphorous entering Lake Erie from the Canadian side was reduced by 82% (Government of Canada, 2018).

A main action which contributed to this major decrease in phosphorous levels was significantly investing in renovating sewage systems to enhance treatment capacity of the returning waters to the rivers and Lake Erie (Government of Canada, 2018).

By the mid 1980s, phosphorus loadings to Lake Erie were less than half the levels of the early 1970s and thus, the frequency and extent of nuisance and harmful algal blooms had declined considerably. In 1989 another legislation (under Canada Water Act and Canadian Environmental Protection Act (CEPA)) was passed to further limit phosphorus concentrations in household detergents (Government of Canada, 2018).

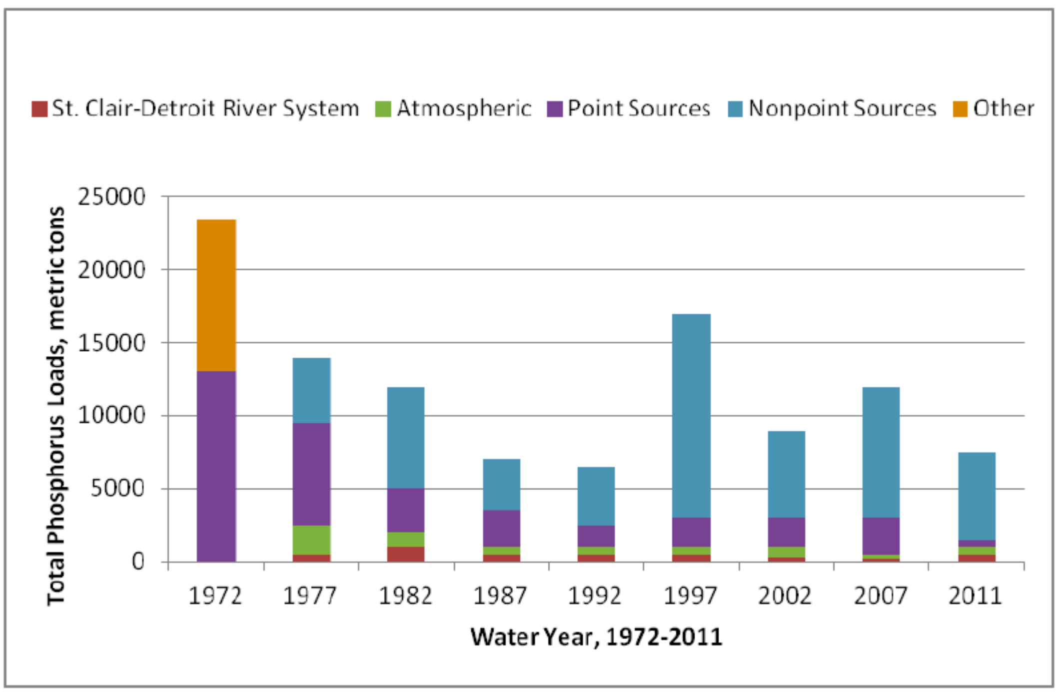

Figure 5.3. Phosphorous Levels in Lake Erie at Different Times (York Region Environmental Services, 2016)

In the early 1990s, the average annual phosphorus load was approximately 10,000 tonnes. However, in the mid 1990s, total phosphorus loadings started rising due to population growth, increased sewage, and more agricultural land use (deforestation).

Moreover, innovations in agricultural technology and fertilizer production after the Second World War, allowed the expansion of hybrid corn production and increased application of commercial fertilizers (Government of Canada, 2018).

There have been many ups and downs in the phosphorous levels from then. The year 2011 was one of the worst among the recent previous years. This was a reason for which since 2012, more than $30 million has been granted to fund more than 8,350 projects in Lake Erie watersheds. On June 13, 2015, Ontario signed the Western Basin of Lake Erie Collaborative Agreement with the U.S. states of Michigan and Ohio. Based on this agreement and other initiatives, these governments committed to 40 per cent total load reduction in the amount of total and dissolved reactive phosphorus entering Lake Erie's western basin by 2025, with an aspirational interim goal of a 20 percent reduction by 2020 (from 2008 base year). Funding for the programs has been the result of many institutions, including Grand River Conservation Authorities' (GRCA) effort to leverage local funds and partnerships with municipal, provincial and federal funding (Government of Canada, 2018).

In sum, Canada, Ontario, the United States and many partners have worked together to reduce phosphorus loadings to Lake Erie for more than 40 years, resulting in significant improvements through the 1970s and 1980s. However, a warming climate, changes in land use and management, and increasing population, have all contributed to a resurgence of algal blooms and other concerns, demanding a new approach (Government of Canada, 2018). As there are many sources of phosphorus and other pollutants (such as artificial sweeteners in the recent years) entering Lake Erie, immediate and collective action by governments, sectors and communities is needed.

Although some of the phosphorous in Lake Erie is due to direct inputs from sources into Lake Erie, much of the phosphorous in Lake Erie comes from rivers flowing into it. And thus, those rivers and their watersheds become increasingly important in maintaining a clean lake. For example, Ontario's Grand River with 70% farming land in its watershed, has one of highest levels of phosphorous and artificial sweetener (a tracer for human wastewater), which all pour into Lake Erie. Neighbouring Cities such as Waterloo, Kitchener, Cambridge, and Brantford have more than 30 treatment plants which pour into Grand River, ultimately affecting phosphorous levels and other toxins in Lake Erie (Government of Canada, 2018).

As mentioned previously, Lake Erie's phosphorous concern has been in the center of attention several times. For this reason, and as an example of an ongoing conflict in a long period of time, it is investigated in this thesis. Two points in time are chosen to be analyzed. Initially, the topic is studied when it first became a concern in late 1960s to early 1970s. And, the second analysis focuses on the current situation.

5.2. 1970s

5.2.1. Causal Loop Diagram

Initially, the status of the stakeholders is investigated through the causal loops approach. In this phase, the different variables of the situation are depicted, and their relationships are analyzed to shed light on the dynamics of the system as a whole (Figure 5.4).

As an example of a negative loop in the diagram, when Algae Bloom levels increased in late 1960s, the water quality was affected extensively, and this raised a lot of social attention and resulted in media speculation that Lake Erie might be "dead" (Government of Canada, 2018). This triggered government initiatives and approved funding to conduct sewage systems renovations followed by more sewage treatment, and reduced phosphorous, and thus, less algal bloom levels in Lake Erie. Each of the other loops in the following diagram can be interpreted in a similar manner.

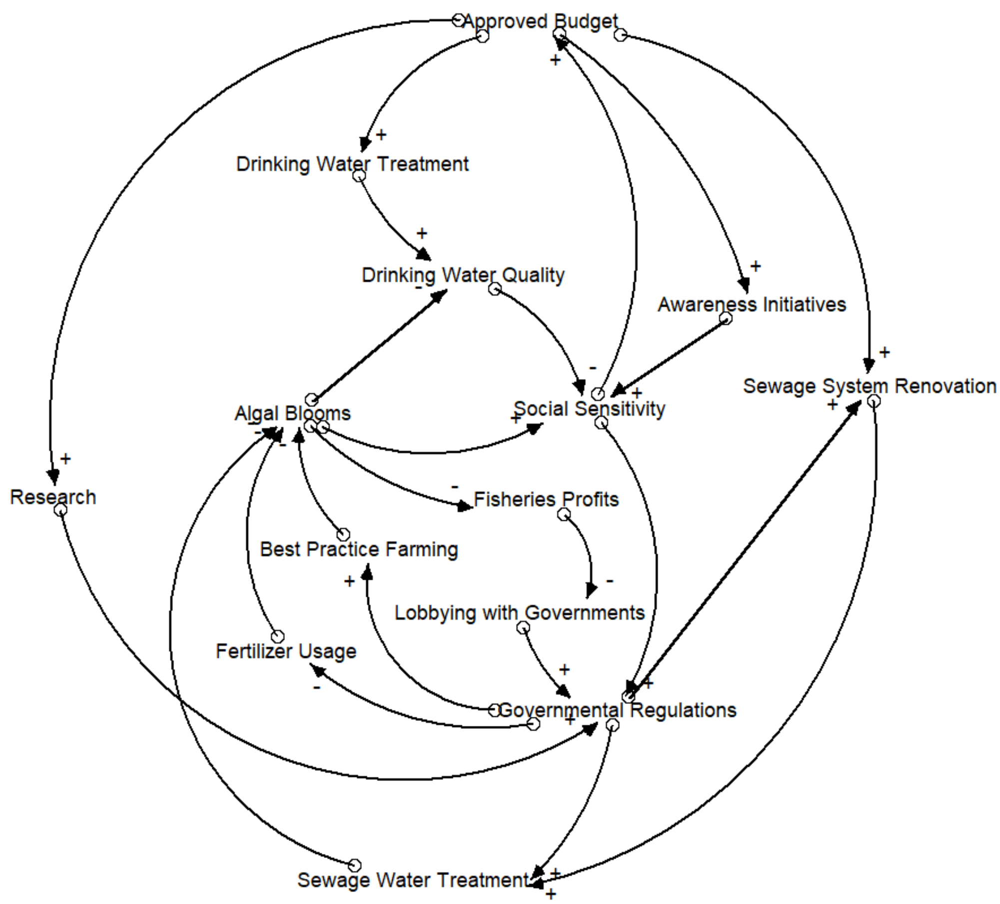

Figure 5.4. 1970s Initial Causal Loop Diagram

Another important happening in the 1970s was that after the increase in algae blooms, fisheries profits started declining, which resulted in their efforts to lobby with the governments regarding setting stricter regulations to pressure businesses to decrease their use of phosphorous. For example, businesses who produced phosphorous-based products such as detergents, and fertilizers, had to change their ways of production. And this would have resulted in a huge decrease of phosphorous levels poured into Lake Erie.

Although studying this initial causal loop helps in understanding the situation, the GMCR model provides much more insight into the conflict at a point in time, since it focuses on the stakeholders, and through a rigorous analytical approach, it reveals a systematic perspective of the situation.

5.2.2. Decisionmakers' Options

Based on a thorough literature review of the situation, it is apparent that the society as a whole became well aware of Lake Erie's soaring pollution levels and the urgent need to handle the crisis back in 1970s. This consensus on the existence and urgency of the topic, brought together many of the important decisionmakers in the system to spend time on the different approaches they could take to deal with the issue.

The authorities were one group of decisionmakers which had the required power to do something about the huge amounts of phosphorous pouring into the Erie Lake. After thorough investigations of the situation, they came up with two possible options to approach the crisis. One was to heavily invest in renewing sewage system infrastructures to lessen point source pollution, originating from tons of phosphorous pouring directly into Lake Erie. The other option was to go back one step, and strictly regulate water management processes to prevent more phosphorous getting into the sewage systems in the first place (Government of Canada, 2018).

Through the investigations, it also became clear then that a main contributor to point source pollution of Lake Erie were businesses and they had to be on board with the authorities, for the crisis management initiative to work more effectively. Therefore, businesses are considered as the second main decisionmaker in this system. Since there were no restrictions set yet for regulating businesses to do anything on this issue, businesses had the option to voluntarily work with the officials on this initiative or not to take part in it.

The possible options of each decisionmaker have been inputted into the below table (Table 5.1) (all GMCRII phases for this set of analysis are shown in Appendix D). Three options are considered for the decisionmakers in this conflict.

Table 5.1. 1970s Decisionmakers and Their Options

Authorities	1	Regulate Water Usage and Treatment Standards
	2	Increase Budget for Sewage Systems Renovations
Businesses	3	Optimize Phosphorous Usage

5.2.3. Feasible and Infeasible States

Each of the three options can be chosen or not by the decisionmakers. The combinations of decisionmakers' decisions (chosen options) develop different states. Therefore, the three options in the current conflict, produce eight (8) states which represent the combinations of the options that might occur. Each state refers to a combination of decisions that could be chosen by the decisionmakers. In Table 5.2, "N" means that the option is not chosen by the decisionmaker. And "Y", means that the option is chosen by the decisionmaker.

Table 5.2. 1970s States

States / Options	1	2	3	4	5	6	7	8
1	N	Y	N	Y	N	Y	N	Y
2	N	N	Y	Y	N	N	Y	Y
3	N	N	N	N	Y	Y	Y	Y

For example, the status quo (the initial condition before the decisionmakers took action) is State 1 in which there were no regulations set by the authorities yet. And the governments were not yet investing in renovating the infrastructure of the sewage systems. And the businesses were not concerned with optimizing their manufacture or usage of phosphorous-based detergents, fertilizers, or other products that much.

There were no infeasible states among the current case's states and all were feasible to occur (the detailed descriptions of all the states are provided in the next section).

5.2.4. Decisionmakers' Preferences

Now, decisionmakers' preferences are ranked from the most preferred to the least preferred state for each decisionmaker (Table 5.3 and Table 5.5).

Table 5.3. Authorities Preferences

States / Options	**7**	**8**	**5**	**3**	**4**	**6**	**2**	**1**
1	N	Y	N	N	Y	Y	Y	N
2	Y	Y	N	Y	Y	N	N	N
3	Y	Y	Y	N	N	Y	N	N

A major preference for the Authorities is that without them going through the long process of developing regulations, the businesses voluntarily optimize their usage levels. However, the Authorities were fine with increasing budget levels to help Cities and businesses in these phosphorous-decreasing activities (i.e. State 7). The Authorities did not however, prefer states in which businesses did not optimize their usage levels. Descriptions of the above states are discussed in Table 5.4.

Table 5.4. Descriptions of Authorities' Preferences

State	**Descriptions of Authorities' Preferences**
7	The main problem identified back in 1970s was to control point sources to ideally prevent or substantially decrease Phosphorus pouring into Lake Erie. Therefore, increasing budget for sewage systems renovations was the first task Authorities had in mind. And thus, it is identified as an initially preferred option. However, regulating water treatment standards is time consuming and costly for Authorities, therefore, the ideal resolution is that Businesses voluntarily show an effort to reach the goal of phosphorus reduction/elimination.
8	Since Option 2, which is increasing renovations budget, is a first priority for the Authorities, and at the same time, Option 3 is important for them as well, State 8 is the next preference for Authorities. It depicts a situation in which for the sake of achieving the objectives, Authorities are ready to design new regulations, in case voluntary conforming of the Businesses is not enough or doesn't work.
5	Option 2, which is increasing renovations budget, is not taken by Authorities in this State (Option 2 is "N"). In this state (State 5), awareness among Businesses is very high to the extent that they prefer to voluntary take action.
3	Authorities prefer to assign budget. This State is preferred even if the Businesses don't act voluntarily.
4	Since assigning budget is an obvious mission for Authorities, State 4 is more preferred than States 6, 2, or 1.

6	Although the main problem is the old sewage system and point sources, Option 2 is not taken in this state.
2	The only action is setting up regulations, which is less preferred for Authorities because this would be a very short-term solution.
1	Due to serious consequences of phosphorous excess (health, safety, and economic consequences), doing nothing is the least preferred state among all.

Businesses preferences are shown in the below table (Table 5.5).

Table 5.5. Businesses Preferences

States / Options	**3**	**8**	**6**	**7**	**1**	**5**	**4**	**2**
1	N	Y	Y	N	N	N	Y	Y
2	Y	Y	N	Y	N	N	Y	N
3	N	Y	Y	Y	N	Y	N	N

Businesses prefer State 3 the most, in which they would not be forced to abide by the regulations set for optimizing usage levels. Descriptions of the above states are discussed in Table 5.6.

Table 5.6. Descriptions of Businesses' Preferences

State	**Descriptions of Businesses' Preferences**
3	Taking care of point source pollution has become a public request and therefore, the Authorities have decided to assign enough budget to renovate old sewage systems (Option 2 is selected by the Authorities). However, in State 3 which is the most preferred state for the Businesses, Option 3 is not selected, meaning that they are not voluntarily optimizing their operations in line with Authorities' initiatives.

8	The budget is increased by the Authorities, and the regulations are strict. In this case, Businesses are committed to optimizing their phosphorous usage. State 8 is the second preference for Businesses, in which the relationship among stakeholders is mostly based on cooperation.
6	The budget is not increased, yet all stakeholders have agreed to cooperate. Businesses have reached to the conclusion that they need to optimize phosphorus usage.
7	Although Authorities only increase the budget and do not take Option 1, Businesses are willing to cooperate.
1	None of the options are chosen by stakeholders. These kinds of states are usually transitional states. Which means, decisionmakers are in the process of making decisions or taking actions.
5	Cooperation is the favorable option chosen by Businesses. However, not taking any options by Authorities is not preferred by Businesses.
4	It is not preferred by Businesses to do nothing, while Authorities increase budget and implement stricter regulations. This can cause the conflicts to get more serious.
2	Only Option 1 is selected in this state. This means increased regulation by Authorities, and no other actions taken. This state is not something Businesses prefer.

5.2.5. Stability Analysis

As mentioned in the previous cases, stability analysis using logical rules (i.e. solution concepts; Table 4.5) that describe decisionmakers' strategic interactions are applied to every outcome in the conflict model in the Tableau Form (Fraser and Hipel, 1979; Fraser and Hipel, 1984) (Table 5.7).

As an example, if the Authorities improve from State 8 to State 7, there is a probability that the Businesses unilaterally improve to State 3 (a less preferred state than State 8 for Authorities). In these situations, it is rational for both decisionmakers to stay at their current state rather than unilaterally improve to begin with. Therefore, State 8 is considered to be sequentially sanctioned for Authorities. In Table 5.7, sequentially sanctioned states for each of the decisionmakers are shown by “S”.

States indicated by “U” in Table 5.7 represent unstable states for a particular decisionmaker. In these states, the decisionmaker has the opportunity to improve to another state. For example, the Businesses can improve from State 5 to State 1. In this case, there is a probability that Authorities move to State 3, which is more preferred for Businesses. Therefore, State 5 is considered as an unstable state for the Businesses.

Table 5.7. 1970s Preferences and Stability Analysis

Authorities								
Overall Stability	X	E	X	E	X	X	X	X
Decisionmaker Stability	R	S	S	R	U	U	U	U
Preference Vector	7	8	5	3	4	6	2	1
UIs		7	7		3	8	4	3
						5		2
Businesses								
Decisionmaker Stability	R	R	R	U	R	U	U	U
Preference Vector	3	8	6	7	1	5	4	2
UIs				3		1	8	6

* E: Equilibrium, R: Rational, S: Sequentially sanctioned, U: Unstable for a particular decisionmaker, X: Unstable for at least one decisionmaker

After identifying the stability of individual states for each decisionmaker, equilibrium states which are stable states for all the decisionmakers are identified. These states are shown by “E” in Table 5.7 and are states in which there is overall stability among the decisionmakers. This is a situation where the decisionmakers have transitioned to other states a few times, and they have reached to an equilibrium which is rational for all decisionmakers, meaning that everyone is stable and cannot unilaterally improve to another state. The remaining states that are indicated by “X” represent states that are unstable for at least one decisionmaker.

State 3 and 8 are stable for both the Businesses and the Authorities while the other states are stable under some but not all solution concepts. Therefore, these two states are considered as the equilibrium, which are also reflected in reality. In State 3, regulations were not implemented since they required a lot of time to be developed and enforced. They only came to effect after 1989. However, the Authorities did assign a lot of budget to renew sewage systems to decrease point source pollution pouting into the Lake. And finally, Businesses did not voluntarily accept to lessen their use of phosphorous in their operations. This was what happened in the short term. However, in the long term, State 8 occurred in which all the three options happened. Not only regulations were developed, and budget was increased, but also businesses optimized their phosphorous usage rates, although not completely voluntarily.

5.2.6. Sensitivity Analysis

The Graph Model, similar to any research model, is an abstract representation of reality. As mentioned before, views of the researcher, or other factors such as the primary and secondary data collection sources, all affect how the model is developed and interpreted.

To decrease the subjectivity of the model, or in other words, assess the robustness of the proposed model, sensitivity analysis is implemented. In sensitivity analysis, the dynamics of the conflict is changed by asking "what-if" questions. This can be done through reasonable changes in the preference ranking of the main decisionmakers of the conflict. The preferences of the decisionmakers are modified based on logical interpretations of the real world existing conditions, and then, if the model yields to similar results to the previously obtained equilibria, it is understood that the model is robust enough to be used in the research. This validates the results from the original model. Alternatively, if the equilibria of the changed model are drastically different from the initial model's results, it shows that the model's original setup requires more thought and calibration.

To conduct a sensitivity analysis for the current case, modifications are implemented on the Authorities preferences (Table 5.8). As can be seen in Table 5.9, the Businesses preference list was not modified in this sensitivity analysis scenario.

Table 5.8. Authorities Alternative Preferences

States / **Options**	**5**	**7**	**6**	**8**	**3**	**2**	**4**	**1**
1	N	N	Y	Y	N	Y	Y	N
2	N	Y	N	Y	Y	N	Y	N
3	Y	Y	Y	Y	N	N	N	N

As mentioned previously, the Authorities understood the importance of eliminating point source pollution in Lake Erie. And one of the main contributors to this pollution, were Businesses. Therefore, in the alternative scenario, it is assumed that the Authorities most preferred States are those in which Businesses voluntarily act upon decreasing their contribution to point source pollution (Option 3 is selected). This brings up States 5, 7, 6, and 8 in the Authorities preference list. As the most preferred state for the Authorities, they prefer to do nothing, and instead, the

Businesses voluntarily and actively cooperate to resolve Lake Erie’s phosphorous concern (State 5).

The other states are ranked assuming that the Authorities would intervene in the process as less as possible. In the first phase they would be fine with assigning more budget to help businesses tackle the problem (State 7). And in the second phase, they would start regulating the industry (State 6). And lastly, and less preferred of course, they would do both (State 8). This trend stands even when the Businesses are voluntarily cooperating to eliminate point source pollution. However, the least preferred state for the Authorities would be to do nothing, in parallel to the Businesses doing nothing as well. This is not at all preferred, since the pollution concern would not be resolved when no one does nothing, and this situation was is not considered at all.

Stability analysis resulting from the above alternative model is summarized in the Tableau Form (Fraser and Hipel, 1979; Fraser and Hipel, 1984) (Table 5.9).

Table 5.9. 1970s Alternative Preferences and Stability Analysis

			Authorities					
Overall Stability	X	X	X	X	E	X	X	X
Decisionmaker Stability	R	S	U	U	R	U	U	U
Preference Vector	5	7	6	8	3	2	4	1
UIs		5	7	6		3	2	4
			5	7			3	2
								3
			Businesses					
Decisionmaker Stability	R	R	R	U	R	U	U	U
Preference Vector	3	8	6	7	1	5	4	2
UIs				3		1	8	6

* E: Equilibrium, R: Rational, S: Sequentially sanctioned, U: Unstable for a particular decisionmaker, X: Unstable for at least one decisionmaker

In this alternative scenario, State 3 became the stable for both Businesses and Authorities. This indicates that the initial model proposed seems to be fairly robust and reliable.

5.2.7. Changes in the System from 1970s to 2010s

As mentioned in Section 3.2 (Methodology used for this Thesis) and Figure 3.4 (Phases of the Currently Used Methodology), now that GMCR is applied on the case, an analysis is conducted on the system's internal and external factors (through the use of the PESTLE model) to understand the changes which happened between 1970s to 2010s.

In the 1970s, the stakeholders were aware to some extent of the non-point source phosphorous pollutions as well as the point source pollutions (Government of Canada, 2018).

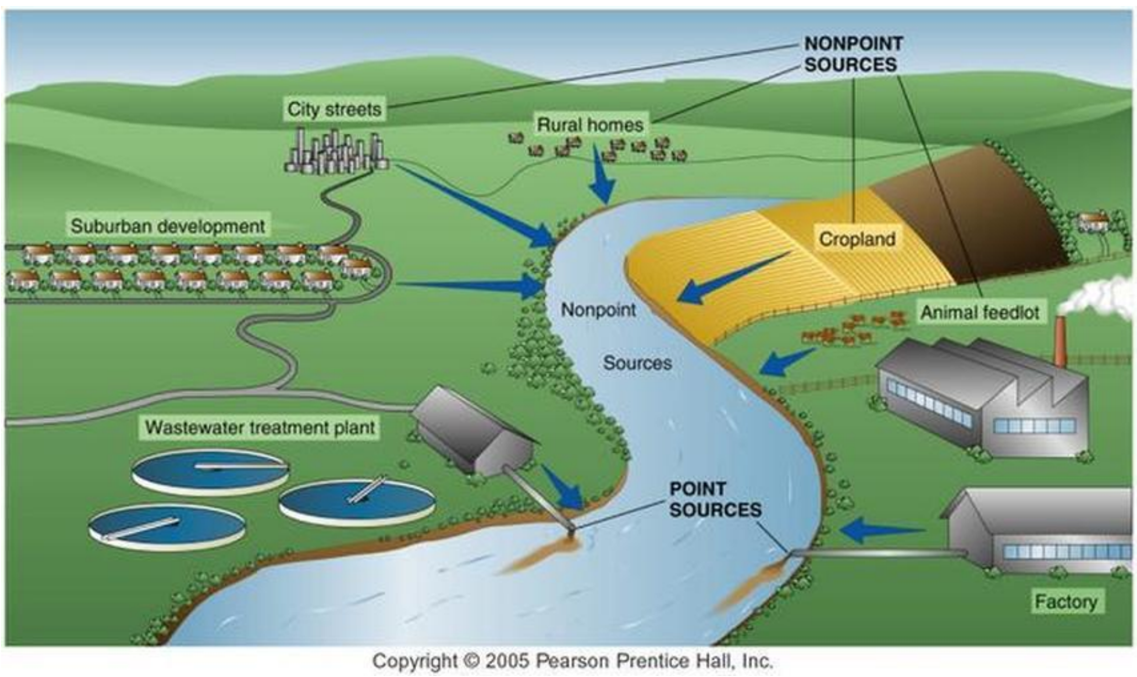

Figure 5.5. Point and Non-Point Source Phosphorous Pollution

However, the focus of the initiatives became centered on eliminating point source phosphorous pollution, since the pollution levels were on a peak, and acting fast and effective had become a priority. Acting against point source pollution was much more straightforward compared to figuring out initiatives to eliminate non-point source pollution. This was the reason that Authorities decided to invest in extensive sewage system upgrades, which led to a tremendous success in decreasing phosphorous levels in Lake Erie.

The other route which was considered to be effective, was to regulate water usage and treatment. However, this was a solution which would not have resulted in immediate decrease of pollution levels. Since regulating was a time consuming approach, and the threats of the pollution were high, Authorities hoped for businesses to voluntarily take action and decrease high phosphorous levels in their products or their operations. However, this was not something that happened, since businesses were not eager to invest money, time, and effort on a non-enforced initiative. This was the overall picture of the conflict after the phosphorous pollution peak of 1970s.

On another note, the external environment has a huge effect on ongoing conflicts among the stakeholders. These external variables affect, and are affected by the stakeholders, but cannot be controlled by them. For example, flooding, changes in the higher political ranks of the country, a national economic recession, unprecedented population growth, are all external variables which negatively or positively affect all the stakeholders such as the government, businesses, and NGOs, but yet, none of these decisionmakers can prevent them from happening.

These external variables change the dynamics of the relationships in a conflict, especially when they occur instantly, and act as a shock to the system. In these instances, the stakeholders are not prepared for the occurrence, and their status in the system changes suddenly. This might raise even more conflicts among the stakeholders, since they are suddenly confronted by more issues to process and resolve, on top of the previous disputes.

After the 1970s, many external changes came to effect, which transformed the situation. For example, increase in the population (i.e. a social/demographic variable) due to immigration, migration, and birth rates in the past decades has been a huge factor in changing the dynamics of the water management system surrounding the Great Lakes, especially Lake Erie, which has one of the most populated watersheds. The increased population use more water, and produce more sewage, which necessitates additional treatment and infrastructure construction and maintenance. The additional water consumption, and the required infrastructure to effectively and efficiently provide safe water for this populated area, is a huge responsibility for relevant governments, and thus, their preferences would lean more towards having more authority and budget to handle the situation better.

The other external factor which hugely affected and is still affecting the situation, is climate change (i.e. an environmental variable). The number of floods hitting the region has increased dramatically in the recent decades, which has increased runoff of non-treated water pouring into rivers that end up in Lake Erie. These act as nonpoint sources of pollution, creating more algae blooms in Lake Erie, which translates into more pressure on businesses and governments to clean their required water (Williams, 2019).

In line with the climate change effects, the temperature in Lake Erie has been changing since 1970. For example, as shown below, Lake Erie temperatures in 2019 have been lower (colder) in Winter, and higher (warmer) in Summers, compared to the past 20 years (NOAA - CoastWatch, 2020). Moreover, precipitation data below shows that June and October precipitation have an increasing trend since 1950, while September and November precipitation have a decreasing trend in the last 2 to 3 decades. Since the 1970s, high annual rates of precipitation have been more frequent (NOAA – Great Lakes Environmental Research Laboratory, 2020; US Army

Corps of Engineers, 2020). Having the previous information in mind, droughts and floods are occurring more nowadays. Droughts make Lake Erie more polluted, since temperature is high and algae blooms grow more. Moreover, floods make the runoffs increase in volume, which results in more pollution of Lake Erie.

Another external variable to the conflict, is the Great Lakes region's financial status (i.e. an economic variable), which is showing a faster growth level than the Canadian economy. The two Canadian provinces and eight U.S. states surrounding the Great Lakes experienced a combined GDP of about $6 trillion USD in 2016. This number was around 5.8 trillion USD in 2015. An interesting fact is that the assuming the Great Lakes region was a country, it would have been the third largest economy in the world, after the U.S. and China (Figure 5.6). This increases the region's ability to focus more investments in water management infrastructure.

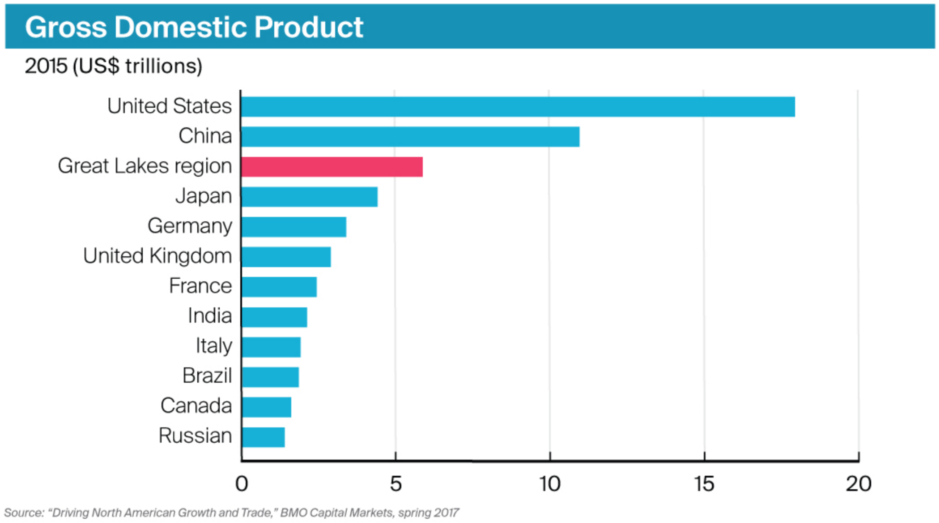

Figure 5.6. Gross Domestic Product of Great Lakes Economy, Assumed as a Country (Kavcic, 2017)

5.3. 2010s

5.3.1. Causal Loop Diagram

Now, we get into analyzing the conflict over the same issue (i.e. rising phosphorous levels in Lake Erie), which was intensified in the 2010s again. The causal loop diagram for the 2010s is provided in the below figure (Figure 5.7).

Figure 5.7. 2010s Initial Causal Loop Diagram

5.3.2. Decisionmakers' Options

Between the two conflict settings in 1970s and 2010s, various changes occurred which transformed the dynamics of the system. One major change was the decision-making weight or importance of the stakeholders involved in the conflict.

As mentioned in the 1970s setting, governments at all levels came to a similar conclusion that Lake Erie is in a critically polluted situation, and that point source pollution needs to be urgently addressed. These decisionmakers also agreed that providing budget will help quickly alleviate the crisis to a high extent, by renovating sewage infrastructure. Moreover, they understood the importance of regulating water management standards, to set strict guidelines for water treatment, distribution, and usage, which guaranteed less pollution pouring into Lake Erie. The clarity established through investigations and reports regarding point source pollution (especially the ancient drainage system), the required budget, and the need for regulations, developed a consensus among governmental stakeholders to join forces and tackle the crisis together.

However, for all their initiatives to work, they also required the support of businesses to lower the amount of phosphorous flowing into sewage systems. Products such as detergents were found to be an important phosphorous source, acting as a major point source pollution. Therefore, in addition to the governmental decisionmakers, businesses were considered an important stakeholder in resolving the issue in the 1970s.

However, as time passed, businesses became less important to the point that they cannot be considered as a main decisionmaker anymore. In the 1970s, eliminating point source pollution was the main focus of the governmental decisionmakers. They tried to convince businesses to voluntarily cut down on their water polluting operations, however, businesses did not cooperate.

The Authorities then started to set strict regulations to force businesses to abide by the enhancement standards, and these regulations came to effect later on in the late 1980s. After the regulations were set up, businesses had to follow the rules, and this was not optional anymore. This decreased the importance of businesses' decisions in this conflict and changed the dynamics of the system.

Moreover, in time, because of the growing complexity in governing cities, and bigger regions, the different levels of authority got divided in their preferences and options. The issue stems from the fact that each level of governmental authority gets assigned different responsibilities by the law, and this requires different, and sometimes opposing types of action.

As an example, currently, regional and/or local governments (Regions and/or Municipalities) are in charge of sourcing quality water for the society, however it is the federal and/or provincial governments which are approving the budget for it. Or as mentioned before, in some cases, the Region provides the water to Municipalities, which finally sell the water to end users. But it is in these interactions between different levels of authority, in which disputes appear. Conflicts on regulation setting, budgeting, or implementation, are some of the disputes which might occur.

So, the main stakeholders in this new setting are governmental authorities. However, these authorities have different options and preferences because of their position in the governmental hierarchy. After extensive data collection which occurred through primary and secondary data gathering procedures, the following options were extracted from the dynamics of the system (Table 5.10). All GMCRII phases for this set of analysis are shown in Appendix E.

Table 5.10 2010s Decisionmakers and Their Options

Regulators	1	Delegating Power to Local Governments for Policy Making and Regulation Development
	2	Providing Budget for Renewing Pipelines, Sewage Systems Renovations, Enhanced Drinking Water Treatment
	3	Development of Auditing Initiatives to Monitor Policy Implementation
Implementers	4	Seeking Authority Over Policy Making and Regulation Development
	5	Lobbying for Increased Budget

As shown in the table, governmental authorities are divided into two main levels. Regulators are considered as high-level authorities which have the regulating power and can also increase or decrease the given budget to local governments such as Cities. They also have the option to audit the activities implemented by the local governments regarding maintaining Lake Erie. The local governments are titled as Implementers, since they have to conduct the policies set by the higher level federal and provincial governments. They prefer however, to develop those policies themselves instead of the higher-level governments. They also seek more budget to implement the set regulations.

5.3.3. Feasible and Infeasible States

The five options in the current conflict, produce thirty two (32) states which represent the combinations of the options that might occur (Table 5.11). Infeasible states in the current case are shaded in this table. In Table 5.11, “N” means that the option is not chosen by the decisionmaker. And “Y” means that the option is chosen by the decisionmaker.

As mentioned before, some of the above states have mutuallly exclusive options and thus, are deemed infeasible to occur. For example, Option 1 is a situation in which the Regulators have already delegated power to the local governments for policy making and regulation development.

Option 4 is a situation in which the Implementers are trying to have more authority over regulation development. So, Options 1 and 4 are mutually exclusive, meaning that they cannot happen at them same time. This restriction, elimnates States 9, 17, 20, 22, 28, 29, 31, and 32 from the model.

The same logic, applies to Options 2 and 5. In Option 2, the Regulators have already provided enough budget for renewing pipelines, sewage systems renovations, and enhanced drinking water treatment. And Option 5 is a situation in which the Implementers are lobbying for increased budget. However, there is no logical reason for Implementers to lobby for more budget, when the Regulators have already accepted to provide enough budget. Therefore, Options 2 and 5 are mutually exclusive options, and whichever state that has these two options selected in them, are considered infeasible to occur and are eliminated from the model. These states are 13, 19, 24, 25, 27, 29, 30, and 32. After deleting the 14 infeasible states, the remaining 18 states are analyzed.

Table 5.11 2010s States and Distinguishing Feasible and Infeasible States (Shaded cells represent infeasible states)

States / Options	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	N	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y
2	N	N	Y	N	N	N	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	N	Y	Y	Y	Y
3	N	N	N	Y	N	N	N	Y	N	N	Y	N	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	Y
4	N	N	N	N	Y	N	N	N	Y	N	N	Y	N	Y	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y
5	N	N	N	N	N	Y	N	N	N	Y	N	N	Y	N	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	N	Y

The feasible states are shown below (Table 5.12). State 17 is the status quo (shaded in Table 5.12), in which the Regulators are not increasing regulations and budget for initiatives regarding Lake Erie anymore. And they have not got into increasingly auditing lower level governments and also businesses regarding their implementation of policies. It is understood that these occur even now, however, these options are intended to show increases in regulations, budget, and audit levels compared to the current situation. In State 17, the Implementers are also lobbying for more authority over policy making and increased budget to initiate programs by themselves.

Table 5.12. 2010s All Feasible States

Options \ States	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	N	Y	N	Y	N	Y	N	Y	N	N	N	N	N	Y	N	Y	N	N
2	N	N	Y	Y	N	N	Y	Y	N	Y	N	Y	N	N	N	N	N	N
3	N	N	N	N	Y	Y	Y	Y	N	N	Y	Y	N	N	Y	Y	N	Y
4	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N	N	Y	Y
5	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y

5.3.4. Decisionmakers' Preferences

The Regulators and the Implementers preferences are shown below in Table 5.13 and Table 5.15. As it can be seen below, Regulators prefer occasions in which Option 1 is "N", meaning that they have not got into developing more regulations and standards. They prefer that the implementers swiftly conduct programs and initiatives without more time and energy put into more policy making.

Table 5.13 Regulators Preferences

Options \ States	5	15	11	18	7	12	1	13	9	17	3	10	6	16	8	2	14	4
1	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
2	N	N	N	N	Y	Y	N	N	N	N	Y	Y	N	N	Y	N	N	Y
3	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	Y	Y	Y	N	N	N
4	N	N	Y	Y	N	Y	N	N	Y	Y	N	Y	N	N	N	N	N	N
5	N	Y	N	Y	N	N	N	Y	N	Y	N	N	N	Y	N	N	Y	N

Descriptions of the above states are discussed in Table 5.14.

Table 5.14 Descriptions of Regulators' Preferences

State	Descriptions of Regulators' Preferences
5	First priority for Regulators in this conflict is the development of auditing initiatives to monitor policy implementation. In other words, they want Implementers to just focus on implementing what they have been told to do, without them complaining or seeking more power and budget. Overall, the Regulators prefer that Option 3 (monitoring of the other stakeholders) be selected. This is why States 5, 15, 11, 18, 7, and 12 are ranked as the most preferred states for the Regulators.
15	From the Regulators point of view, the Implementers lobbying for more budget (Option 5 being selected) is more preferred than them seeking an increase in more authority.
11	In State 11, the Regulators are still monitoring the Implementers, however, the Implementers seek more authority over policy making and regulation development.
18	In this state, the Implementers have selected both their options (Option 4 and 5 are selected by the Implementers). However, the Regulators are only monitoring the Implementers' performance, without getting into approving budget or more authority for the Implementers.
7	From State 7 to State 17, preference prioritization is mostly based on the Implementers options. Regulators still prefer to monitor the Implementer's performance and at the same time, they provide the required budget for renewing pipelines, sewage systems

	renovations, and enhanced drinking water treatment (Option 2 is selected).
12	Here, the Regulator's decision is the same as State 7 (Option 1 is not selected, but Options 2 and 3 are selected). The Implementers select Option 4. This state indicates a situation in which monitoring is important for Regulators, and at the same time, delegating power to the Implementers (Option 5) is not selected.
1	None of the options are taken by any of the stakeholders. As mentioned before, these states are usually transitional states. This means that decisionmakers would not be permanently staying in them, since they will be transitioning to other states.
13	In this state, the Implementers have chosen their Option 5, which means that they are actively lobbying for more budget. None of the other options are taken by the decisionmakers.
9	The Implementers have chosen their Option 4 in this state, meaning that they are actively lobbying for more authority. None of the other options are taken by the decisionmakers.
17	The Implementers have chosen to lobby for both budget and authority.
3	This state is a situation in which the Regulators have provided budget for renewing pipelines, sewage systems renovations, and enhanced drinking water treatment. None of the other options are selected by the decisionmakers.
10	This state is a combination of Option 2 taken by the Regulators, and Option 4 taken by the Implementers.
6	From State 6 to the end of the preference list, the preferred states are prioritized mostly based on the Regulators' selections.

	Generally, choosing Option 1 (approving more authority for the Implementers) is the least preferred option for the Regulators. So, States 6, 16, 8, 2, 14, and 4 are ranked last in their preference list table. Moreover, the Regulators initial preference is to keep performance monitoring (Option 3 being selected). Therefore, States 6, 16, and 8 are preferred more over States 2, 14, and 4.
16	In State 16, in addition to Options 1 and 3 being selected by the Regulators, Option 5 is selected by the Implementers.
8	All the first three Options are selected by the Regulators, meaning that they have approved more budget, and more authority for the Implementers, but at the same time, they continue monitoring their performance to ensure they are actively abiding by the standards and budget guidelines.
2	States 2, 14, and 4 are situations in which the Regulators have not chosen to monitor the Implementer’s performance (Option 3 not selected). In State 2, the Regulators have approved more authority for the Implementers, and the Implementers are not lobbying for more power or budget.
14	This state is similar to State 2, however, the Implementers are seeking increased budget for further renovations. In this state, the Regulators have delegated more authority to the Implementers for policy making and developing regulations. This is one of the least preferred states in the Regulator’s point of view.
4	The Regulators least prefer this state. In State 4, the Regulators have approved more authority and budget for the Implementers. However, they are not monitoring their performance.

The Implementers initially prefer states in which they are not spending much energy into lobbying for more power and budget. In their eyes, this energy can be put on more work on programs focused on Lake Erie instead (Table 5.15).

Table 5.15 Implementers Preferences

Options \ States	4	8	10	3	12	7	14	2	16	6	17	13	9	1	18	15	11	5
1	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N
2	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
3	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y
4	N	N	Y	N	Y	N	N	N	N	N	Y	N	Y	N	Y	N	Y	N
5	N	N	N	N	N	N	Y	N	Y	N	Y	Y	N	N	Y	Y	N	N

Descriptions of the above states are discussed in Table 5.16.

Table 5.16 Descriptions of Implementers' Preferences

State	Descriptions of Implementers' Preferences
4	Sorting each decisionmakers' preference is affected by their own options and of course, their rival's options. For example, State 4 is the most preferred status for Implementers. In this ideal situation, the Regulators delegate more power and provide budget to Implementers, without enforcing the pressure of monitoring them (Option 1 and 2 selected, but Option 3 not selected). So, the Implementers are receiving more authority and more budget, without putting an effort to lobby for increased budget and authority (Options 4 and 5 not selected),
8	State 8 is less preferred than State 4 for the Implementers. In this state, although the regulators have delegated more authority and budget to the Implementers, they are monitoring the Implementers performance as well.

10	The first two preferred states for the Implementers was a situation in which both Options 1 and 2 were selected by the Regulators. However, after these two states, the Implementers prefer to at least be provided with more budget by the Regulators, even if they are not provided with more authority to set regulations. This is why States 10, 3, 12, and 7 are ranked as the next preferred situations for the Implementers. Since the Implementers prefer to have more authority as well, they lobby for more power as well (Option 4 is selected by them).
3	The Regulators have provided more budget, and the Implementers are happy with this. However, the Implementers are not seeking more authority. This state is less preferred than State 10.
12	In this state, the Regulators have taken on monitoring the Implementers (Option 3 selected), so the Implementers seek authority (Option 4 selected) to balance the Regulators' power to some extent.
7	In this state, the Implementers will only make the best of the additional budget provided by the Regulators.
14	As mentioned before, the most preferred states from the Implementer's point of view are when the Regulators delegate more power, and increase budget at the same time, while the Implementers do nothing. This occurs in States 4 and 8. The Implementers second set of preferred states is when the Regulators choose Option 2, even though they haven't chosen Option 1. This is why States 10, 3, 12 and 7 were ranked after States 4 and 8 in the Implementer's preference list. The third set of preferred states for the Implementers is when the Regulators provide more authority to the Implementers, in decision makings

	regarding managing water systems (States 14, 2, 16 and 6) In these States, Option 1 is selected (more power is delegated), but not Option 2 (more budget is not provided). Between the four states mentioned (14, 2, 16, and 7), States 14 and 2 are more preferred since the Regulators are not putting more pressure on the Implementers through monitoring them. And finally, State 14 is more preferred than State 2 for the Implementers, since the Implementers prefer to lobby for more budget (Option 5 is selected), because the Regulators have not chosen Option 2 (more budget is not approved).
2	This state is similar to State 14, however, the Implementers have decided to do nothing regarding lobbying for more budget.
16	The Regulators provide more power to the Implementers (Option 1 selected), however, they initiate monitoring to control how the Implementers perform (Option 3 selected). The budget issue still exists for the Implementers, so they prefer to lobby for more budget (Option 5 selected) rather than do nothing.
6	The Regulators decisions are the same as State 16. However, the Implementers take no action.
17	States 17, 13, 9, and 1 are ranked next in the list of preferences, and not favorable from the Implementer's point of view. These states indicate situations in which the Regulators take no action at all (Options 1, 2 and 3 not selected). Among these states, the Implementers first prefer to seek authority and budget at the same time (Options 4 and 5 selected) to gain the most control over managing water systems
13	As mentioned before if the Implementers have to select between increased budget and more power, they prefer to have more

	budget. Thus, they select Option 5 (lobby for more budget) in State 13.
9	State 9 is less preferred than State 13, since the Implementers solely seek more authority (Option 4 selected) instead of more budget (Option 5 selected).
1	Neither of the decisionmakers take their options. As mentioned before, this state is a transitional state, meaning that it is not stable.
18	States 18, 15, 11, and 5 are least preferred states for the Implementers. The reason is that the Regulators have not delegated more authority and budget to the Implementers (Options 1 and 2 not selected), and worse, they are monitoring the Implementer's performance as well (Option 3 selected). This puts the highest amount of pressure on the Implementers in regards to managing water systems. In State 18, which is the most preferred among the four mentioned states, the Implementers are trying their best to get more authority and budget from the Regulators (Options 4 and 5 selected).
15	After State 18, State 15 is preferred. In this state, although the Implementers are not lobbying for more power, but they are trying to get more budget, as this is more urgent for them.
11	After State 15, in which the Implementers are seeking more budget, State 11 is considered, in which the Implementers try to at least receive more power, now that do not have access to more budget.
5	The worst situation in the Implementers' point of view is to not be provided with more power and budget (Options 1 and 2 not selected), be under more pressure through being monitored by

the Regulators (Option 3 selected), and finally to not seek any more power and authority (Option 4 and 5 not selected).

5.3.5. Stability Analysis

Current case's equilibrium state (which is rational for all decisionmakers, meaning that everyone is stable and cannot unilaterally improve to another state) is shown by "E" in the Tableau Form (Fraser and Hipel, 1979; Fraser and Hipel, 1984) (Table 5.17). The remaining states that are indicated by "X" represent states that are unstable for at least one decisionmaker.

Table 5.17. 2010s Preferences and Stability Analysis

Regulators																		
Overall Stability	X	X	X	E	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Decisionmaker Stability	R	R	R	R	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Preference Vector	5	15	11	18	7	12	1	13	9	17	3	10	6	16	8	2	14	4
UIs					5	11	5	15	11	18	1	12	5	15	7	1	13	3
											7	9			6	6	16	8
																		2
Implementers																		
Decisionmaker Stability	R	R	R	S	R	S	R	S	R	S	R	S	S	S	R	U	U	U
Preference Vector	4	8	10	3	12	7	14	2	16	6	17	13	9	1	18	15	11	5
UIs				10		12		14		16		17	17	13		18	18	15
														9				11

* E: Equilibrium, R: Rational, S: Sequentially sanctioned, U: Unstable for a particular decisionmaker, X: Unstable for at least one decisionmaker

State 18 (N, N, Y, Y, Y) is stable for both the Regulators and the Implementers while the other states are stable under some but not all solution concepts. Therefore, State 18 is the equilibrium state in this model.

State 18 is a situation in which the Implementers are seeking authority over policy making and regulation development to have more control over what happens in their vicinities. They also try to get more budget from the higher-level authorities to become more flexible on their spending and water management capabilities. However, the Regulators would not delegate regulating power to local governments. The Regulators tend to keep that authority for themselves, so that they would be able to maintain power and consistency among their Regions, or Provinces. In addition to this, they would develop auditing initiatives to monitor how the local governments are implementing the set policies. Moreover, the Regulators would not provide huge amounts of budget for the Implementers.

As mentioned before, State 17 is the status quo of the situation, meaning that it is what is currently happening in the real world. State 17 (N, N, N, Y, Y) is very similar to State 18 (N, N, N, Y, Y) in that the Regulators are not approving more budget and authority for the Implementers, and the Implementers are lobbying for more budget and power over policy making. The only difference is the fact that currently monitoring initiatives to audit the Implementers' performance are not heavily conducted in the real world. However, based on the GMCR model, and also based on the interviews conducted throughout this research, the system is transitioning from State 17 to State 18, in which not only more budget and authority have not been approved by the Regulators, but also more monitoring would be conducted on the Implementers in the near future (anonymous interviewee #4, personal communication, 2020). An insight into these results is provided in section 5.3.8 of this Chapter.

5.3.6. Sensitivity Analysis

Similar to the previously conducted sensitivity analysis on the conflict in 1970s, a modification of preferences is conducted here as well, to ensure the robustness of the developed model. This validates the obtained results, making sure the model is reasonably built and that the results are a reflection of the existing real-world conflict. To test the robustness of the 2010s conflict with an even more challenging sensitivity analysis than the one conducted for the 1970s conflict, preference ranking of both decisionmakers are modified.

The modifications assumed for the Regulators preferences are shown in Table 5.18.

Table 5.18 Regulators Alternative Preferences

States / Options	5	15	11	18	1	13	9	17	7	12	3	10	6	16	8	2	14	4
1	N	N	N	N	N	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
2	N	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	Y	N	N	Y
3	Y	Y	Y	Y	N	N	N	N	Y	Y	N	N	Y	Y	Y	N	N	N
4	N	N	Y	Y	N	N	Y	Y	N	Y	N	Y	N	N	N	N	N	N
5	N	Y	N	Y	N	Y	N	Y	N	N	N	N	N	Y	N	N	Y	N

It was mentioned in the original model that the Regulators prefer states in which Option 3 is selected by them. This was because they intended to make sure that the Implementers are being monitored regarding how they are performing. This is why States 5, 15, 11, 18, 7, and 12 were ranked first in the preference list (Table 5.13). Also, in that model, it became apparent that the Regulators preferred that they don’t approve more authority for the Implementers. This was because the Regulators did not want to lose control of managing the system. This was the reason that States 6, 16, 8, 8, 2, 14, and 4 were ranked as the least preferred states in the list (Option 1 is selected). In the new setting, it is assumed that in addition to avoiding delegating authority, the Regulators also try to avoid approving more budget as much as possible (Option 2 not being selected). This is why States 7 and 12 moved down the preference list, after States 1, 13, 9, and 17.

Modifications regarding the Implementers are shown below in Table 5.19.

Table 5.19 Implementers Alternative Preferences

States / Options	4	8	14	2	16	6	10	3	12	7	17	13	9	1	18	15	11	5
1	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
2	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N	N	N	N	N	N	N
3	N	Y	N	N	Y	Y	N	N	Y	Y	N	N	N	N	Y	Y	Y	Y
4	N	N	N	N	N	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
5	N	N	Y	N	Y	N	N	N	N	N	Y	Y	N	N	Y	Y	N	N

In the originally developed model, the Implementers preferred that the Regulators provided them with increased budget to renovate infrastructure (Option 2 is selected). Therefore, States 4, 8, 10, 3, 12, and 7 were ranked as the most preferred states in the Implementer's perspective. However, in the alternative scenario and for the sake of sensitivity analysis, it is assumed that the Implementers prefer to be provided with more authority as a most preferred situation (Option 1 is selected). Therefore, States 4, 8, 14, 2, 16, and 6 are placed as the most preferred states in the Implementer's preference list.

Stability analysis resulting from the above alternative model is summarized in the Tableau Form (Fraser and Hipel, 1979; Fraser and Hipel, 1984) (Table 5.20).

As mentioned before, "what-if" questions are asked in sensitivity analyses to test the robustness of the model. Different assumptions were made here regarding the preference rankings of the decisionmakers to assess the robustness of the initial model.

Table 5.20. 2010s Alternative Preferences and Stability Analysis

Regulators																		
Overall Stability	X	X	X	E	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Decisionmaker Stability	R	R	R	R	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Preference Vector	5	15	11	18	1	13	9	17	7	12	3	10	6	16	8	2	14	4
UIs					5	15	11	18	5	11	1	12	5	15	6	1	16	8
											7	9			7	7	13	3
											5	11				5	15	
Implementers																		
Decisionmaker Stability	R	R	R	S	R	S	R	S	R	S	R	S	U	U	R	U	U	U
Preference Vector	4	8	14	2	16	6	10	3	12	7	17	13	9	1	18	15	11	5
UIs				14		16		10		12		17	13	9		18	15	11
													17	13			18	15

* E: Equilibrium, R: Rational, S: Sequentially sanctioned, U: Unstable for a particular decisionmaker, X: Unstable for at least one decisionmaker

In this alternative scenario, State 18 became stable for both Regulators and Implementers. Since the originally developed model resulted in State 18 becoming the equilibrium, and State 18 has showed itself as a stable state for all decisionmakers in the alternative model as well, it can be concluded that the initial proposed model is robust and reliable.

5.3.7. Insights from the 1970s External Analysis

Having gone through the Lake Erie pollution issue through time, it can be seen that many internal and external variables have occurred, changing the dynamics of the system. Change of dynamics, translates to change of stakeholders, their options, their preferences, and also, the overall context of the environment in which the conflict exists. So, if a decisionmaker can foresee these changes, it can try to adapt to them sooner and more effectively, to ensure a better status for itself in the future.

Firstly, it was mentioned previously that after the 1970s, many external changes came into effect, which transformed the situation. In section 5.2.7, changes that occurred between 1970s and 2010s were discussed. Population increase, climate changes, and economic growth were the most important occurring variables after the 1970s.

Secondly, it was shown in the 2010s case analysis that State 18 was the equilibrium state (was stable for both local-level governments [Implementers] and high-level governments [Regulators]). However, as shown in Table 5.15 (Implementer's Preference List), State 18 is not at all among the most preferred states in the Implementers perspective. In this state, the Regulators do not approve more authority and budget for the Implementers, forcing the Implementers to put a lot of energy and effort into lobbying for more power and money. Moreover, in State 18, the Regulators are monitoring the Implementer's performance to ensure they are acting in accordance with the set regulations.

With these two introductory points in mind, it can be suggested that if the local governments such as Municipalities (Implementers in the 2010s case) had been aware of the external variables occurring in the future years after 1970s, they would have been able to actively intervene in the dynamics of the disputes to avoid ending up in State 18 in the 2010s.

The Great Lakes watershed population increase, especially in the Lake Erie region, resulted in more used water, more produced sewage, and thus, more required water treatment, in addition to more infrastructure construction and maintenance. The responsibility of providing services for this increased population, necessitated more authority and power for the local governments. And this was the reason why lobbying for, and receiving more authority and budget from the higher-level authorities (Regulators), became important options in the 2010s.

However, assuming that the local governments were aware of this population increase, they could have started lobbying for more authority and budget much sooner, when they were hand in hand with the higher-level authorities dealing with the pollution concern back in 1970s. As a reminder, both local and high-level authorities were on the same side back in 1970s, when all investigations resulted in the same results, stating that phosphorous pollution was a serious environmental issue, and had to be dealt with as soon as possible. This unanimous agreement on the urgency to handle the pollution in 1970s, would have been a great opportunity for the local-level governments to lobby for more authority and budget, had they known the extra load that population would be putting on them in the years to come.

If the local governments had been delivered the required authority and budget shortly after or during the 1970s, the 2010s conflict analysis would have looked differently than it does now. With the additional power for regulating the industry, and also, the needed budget to enhance water management infrastructure in the region, the local governments would not be seeking more budget and authority. Moreover, building on the cooperation developed among the different levels of the government in the 1970s, the local governments would have been able to develop trust towards themselves, which would have eliminated the need for their performance being closely monitored in the 2010s.

Overall, with the local governments actively participating in trust building initiatives, and also, lobbying for more authority and power in the 1970s, after their successful cooperation with the higher level authorities in resolving the issue, the 2010s equilibrium state would have been State

4. In this state, which is the most preferred state for the Implementers in 2010s, budget and authority for the Implementers would have already been approved (Option 1 and 2 selected). Option 3 would not be selected (monitoring of the Implementers would not be felt necessary by the Regulators). And Options 4 and 5 would also not be selected by the Implementers since they already received the required money and power to regulate the industry as they see fit. All this is assuming that the 2010s Options list (Table 5.10) or the main decisionmakers would not have changed because of the proposed changed dynamics between the Implementers and Regulators after the 1970s.

A similar line of reasoning can be provided for the other external variable occurring after the 1970s. Climate change, as an environmental external factor, dramatically increased flooding, which in turn increased runoffs of non-treated water pouring into rivers, which then ended up in the Great Lakes, including Lake Erie. This increased building up of algae blooms, put more pressure on authorities to treat the water before and after use (Williams, 2019). Similarly, other environmental factors such as intensified fluctuating temperatures since the 1970s (NOAA - CoastWatch, 2020), and recurrent high annual rates of precipitation (NOAA – Great Lakes Environmental Research Laboratory, 2020; US Army Corps of Engineers, 2020), increased pollution levels in the Great Lakes, putting more strain on the authorities to effectively manage water systems.

Had the local governments anticipated these dramatic climate change effects back in 1970s, they would have been able to change the dynamics of the situation, to avoid arriving at State 18 in the 2010s. An effective strategy by the Implementers to build trust and develop confidence in themself, would have been to pioneer climate change awareness initiatives for the Regulators, letting them know of the extra load climate change will be imposing on the region's water management systems in the years after 1970s. These educational initiatives would have helped the Regulators understand the necessity of thoroughly preparing for climate change effects, providing more budget for renewing pipelines, sewage systems renovations, and enhanced drinking water treatments. And these awareness initiatives taken place by the Implementers would have given the Regulators the confidence they required, to not see the need for administering additional monitoring and evaluation systems on the Implementers. Therefore, the equilibrium state in the 2010s would have again ended up in State 4, which is the most preferred state for the Implementers.

The third and final external factor which was focused on in section 5.2.7, was the Great Lakes region's financial status, showing a high growth rate, faster than the rest of the Canadian economy. This successful economy is to the extent that if Great Lakes was considered a country, it would have been the third largest economy in the world, after the U.S. and China.

Predicting this economic growth, the local governments (Implementers in the 2010s) could have increased their lobbying efforts and political activities after the successful management of the pollution issue in 1970s, to increase their share of the economic prosperity in the coming years. Employing this approach after 1970s, would have enabled them to lessen their need for more budget in the 2010s.

In sum, foreseeing external variables after the 1970s, could have helped the Implementers arrive at a better position in the 2010s in regards to budget, authority, and trust in their performance.

5.3.8. Insights from the 2010s External Analysis

As discussed previously in the methodology section, important external variables affecting the system dynamics of the conflict of interest, and also the scenarios they precipitate, are investigated in this section. The following scenarios are categorized based on each of the PESTLE model variables, however, most of the scenarios include a situation in which two or more of the PESTLE variables occur together. To clarify, although a section is devoted to political scenarios, many of them enforce an economic shock to the system as well.

5.3.8.1 Political Atmosphere and Legal Challenges

Donald Trump, the U.S. President (White House Office of Management and Budget), proposed funding cuts (from $300 million a year) to the Great Lakes Restoration Initiative (GLRI) several times during the past few years (Matheny, 2017). This became a source of worry for many businesses and NGOs dependent on the funding. However, Congress overruled President Trump by giving the program $300 million each year, bringing Congress side-by-side with businesses and NGOs supporting the initiative. On the 28th of March 2019, Trump pledged to support the total $300 million funding, aligning himself with the other decisionmakers which stand for the funding (Skalka, 2019).

This represents an example of a political variable affecting the stakeholders of the Great Lakes. Until March 2019, NGOs and other similar decisionmakers were worried, and had to spend millions in lobbying for receiving funding, but then, something positive and out of their control happened, which put them in a much better position regarding budgeting. In other words, a sudden external political variable, changed the dynamics of the system.

Focusing on Canada, local municipalities and regions in Ontario, are environmentally concerned. Many initiatives are taking place, but as a broader perspective, local governments have understood that water conservation initiatives do not only save water, but also save energy and thus, reduce greenhouse gas emissions. This stems from the fact that treatment of the used water, requires a lot of energy to be pumped back and forth. And therefore, by conserving water, the energy required to treat the used water is also conserved.

However, the Doug Ford administration (Premier of Ontario; Provincial Government), has downplayed the problem with greenhouse gases, and this might become the next serious dispute in the system (anonymous interviewee #1, personal communication, 2020). Decreasing funding for environmental initiatives in Ontario from 2019, has expanded to different programs in the Province. For example, Ontario conservation authorities announced that the Provincial government has cut their flood management funding in half (from $7.4 million). This funding is used to forecast flooding, issue warnings, monitor stream flow, regulate development activities in flood plains, educate the public about flooding and protect natural cover that helps reduce the impacts of flooding.

But as mentioned in previous sections of this thesis, Ontario is experiencing stronger and more frequent flood occurrences as a result of recent climate change effects. Conservation Ontario, which is a representative of the province's 36 conservation institutions, which oversee watershed management and other ecological matters, said the cuts would impact the region immediately (Jones, 2019).

Some of the other actions by the new provincial administration, other than cutting the flooding management funding, are as follows (Xing, 2019):

- The cap-and-trade program was cut. This initiative capped greenhouse gas emissions, however, it allowed polluters to buy or trade exemptions.
- The office of the environmental commissioner of Ontario was eliminated.
- Funding to the Ministry of Natural Resources and Forestry was reduced.
- Funding to the Ministry of the Environment, Conservation and Parks was reduced.

The above actions affect the dynamics of the relationships among the relevant stakeholders. If the budget cuts continue, cities and regions would not be able to invest in initiatives to increase water conservation, increase society awareness, and decrease non-point source pollution of the Great Lakes, especially Lake Erie.

Another political factor affecting the Great Lakes, is the relationship between US and Canada. The disagreements between Prime Minister Justin Trudeau and President Donald Trump on topics such as economics and environmental initiatives, might be one of the important political aspects one must investigate to understand the potential political changes affecting Great Lakes and related ongoing conflicts.

It was discussed in the previous section on 1970s external analysis that investigating or becoming aware of external variables could have helped local-level governments to better manage the situation in 1970s towards an enhanced state in the 2010s. Similarly, the Implementers can make use of a thorough external analysis in 2010s to improve their position in the upcoming potential conflicts in the future. Currently, the Implementers stand at State 18, in which they have to put forth a lot of effort on lobbying for more authority and money from the higher-level authorities.

The mentioned political changes in Canada and the US seem to be constantly affecting the local-level governments dealing with the Great Lakes. Becoming aware of these political external variables, local-level governments could actively intervene in the system to change their status from State 18, in which they have to rigorously lobby for more authority and budget.

An action which might be of help to them, is to try to depoliticize climate change in the higher-level authorities' perspectives. If water management and its related concerns become less political and more scientific in the eyes of the public as a whole, changes in the political administrations would have less effects on the stability of policies and funding of water management initiatives. To get to this point, the local governments can proactively educate the society about climate change, its effects on water management systems, and of course the urgency of required funding to lessen its effects on the environment and the society.

Investigating the legal factor of the PESTLE model, it is understood that the Ontario government is trying to persuade farmers to voluntarily reduce fertilizer use on their farms. They are adopting new technologies, such as computerized systems and mapping that assist them in using fertilizers more efficiently. They are also promoted to change their farming practices such as burying fertilizer beside seeds when planting, rather than leaving it on top of the ground, where it might be washed away. Although all this is being done voluntarily for most parts, restricting and enforcing farmers through new regulations, will have a huge effect on the stakeholders of the Lake Erie pollution issue. The costs for the farmers and agricultural businesses would increase, leading to their frustration and less cooperation with governmental stakeholders of the conflict (anonymous interviewee #1, personal communication, 2020). Having these frustrations in perspective when making decisions and regulations, would assist local governments to build trust with the agricultural businesses to prevent further conflicts with them in the coming years.

5.3.8.2. Social and Demographic Trends

Population growth (birth and immigration) is a major external variable which accounts for increases in Lake Erie becoming more polluted with phosphorous. The increase in population in Ontario, is highest among all Great Lakes watersheds. Ontario's population is projected to increase by 38.0 percent in the next 26 years, from about 14.3 million on July 1, 2018 to about 19.8 million by July 1, 2046. Eighty two (82) percent of this population growth, is projected to be because of migration, and birth accounts for the remaining 18 per cent. The Greater Toronto Area (GTA) seems to be the fastest growing region of the province, and shows an increase in population from 6.8 million in 2018 to about 10.2 million in 2046 (Government of Ontario, 2020c).

Increased population translates into increased sewage, more agricultural land use (deforestation) and thus, more loadings from agricultural land, increased water extraction, and in sum, more Lake Erie water demand, and less the quality of the water.

These population growth trends significantly change the dynamics of the system through different processes. The budget required to extract, and treat more drinking and sewage water, and the money needed to initiate water awareness campaigns for more people, are only some examples of the burdens on Cities, and other governmental decisionmakers, who are important stakeholders in the current conflict. Regions' and Cities' responsibilities over water sourcing for more people is a challenge that requires more budget to deal with. However, the increased population has put more loads on the whole Province, and thus, the provincial and federal governments might also be under pressure, which limits their ability to increase Cities' budgets. This intensifies the already ongoing conflict on budgeting. It can however, strengthen Regions' and Cities' stances in regards to having more authority over decision making, which is a major preference in the investigated conflict, as discussed in the Implementers preference table (Table 5.15).

The social factor in the PESTLE model, not only covers population growth and regional demographic changes, but also social awareness trends for or against ongoing issues (Aguilar, 1967; Perera, 2017). For example, the social trend towards being environmentally friendly or eating more organic food, has been on the rise, and has affected many fast food restaurants. The same applies to our conflict. The fact that more people are aware of climate change consequences, changes the way they use water in their day to day lives. In line with this trend, the effectiveness of the awareness initiatives run by governments and NGOs to protect water sources (such as the digital marketing campaign by Canada and Ontario to build awareness of the need for actions to reduce phosphorous in the Lake Erie), would be enhanced, and in result of this, less budget might be required to implement such initiatives since people are already aware of the situation, and thus, require less effort and spending to convince. As seen in Figure 5.8, the total water use in Canada declined from 485 litres person per day in 2011, to 427 liters in 2017 (12% decrease).

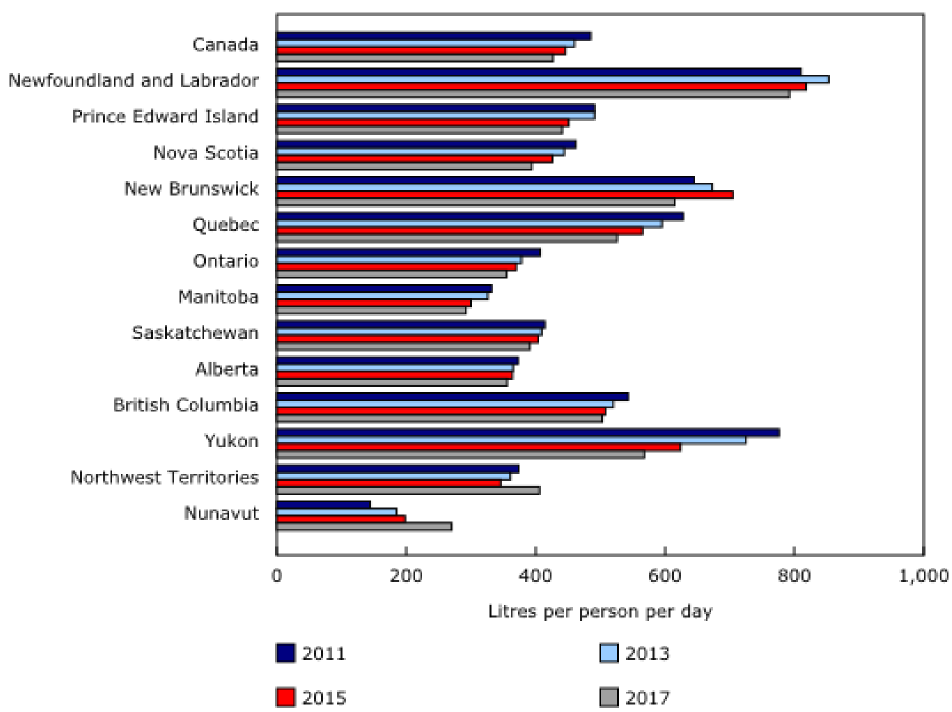

Figure 5.8. Average Daily Total Liters of Water Per Capita in Canada and its Provinces

(Statistics Canada, 2019)

Trying to increase awareness in the society in regards to water conservation can be a policy that authorities can continue to adopt to resolve concerns regarding regional water scarcity in the coming years.

5.3.8.3. Economic Concerns

The federal and provincial governments are developing and running programs with multi-million dollar commitments to sustain the quality of Lake Erie. Industry decisionmakers are also trying to help these initiatives, although, the budget required for these programs is mostly provided by the governments.

As mentioned before, the budget required to run awareness programs, in parallel to additional costs from increased treating and maintenance of water sources, and other costs such as distribution and floodwater challenges, all impose a huge pressure on the governmental institutions. The growing population discussed in the "Social and Demographic Trends" section, exacerbates the situation, and the pressure on governmental institutions runs down to businesses, NGOs, and the society at large.

The other demographic trend which should be considered, is the rapidly aging population in Canada. By 2030, roughly 25 per cent of Canadian citizens will be seniors, up from 17 per cent today. Baby boomers are entering retirement, and these trends will pose a huge financial load on the government as benefits to the older generation, "are expected to double in the next ten years from $56 billion today (2019) to $99 billion" (Snyder, 2020). This decreases government's spending ability on infrastructural initiatives, which translates to less budget for water management projects, and thus, more disputes or conflicts among water management stakeholders.

These additional potential economic pressures on higher-level governments should be investigated more in depth. And the local governments could use these investigations' reports to better understand the higher-level authorities' situation. This insightful understanding can then assist the lower-level governments to achieve better deals when negotiating for more authority and budget with the higher-level authorities.

A recession of some magnitude, occurring because of sudden external environments such as the COVID-19 pandemic, can also impact the dynamics of the system, as it might slow down or completely halt water infrastructure construction projects and other water conservation initiatives. This situation is discussed in the upcoming multivariable external shocks section.

5.3.8.4. Technological Advancements

The technological advancements factor in the PESTLE, is a double-edged sword in the current system. For example, innovations in agricultural technology and fertilizer production after the Second World War, allowed the expansion of hybrid corn production and increased application of commercial fertilizers (Government of Canada, 2018). This in turn, substantially increased the phosphorous amounts pouring into Lake Erie to up to 28,000 tonnes per year in 1968. This might well happen in the coming years as well. Other technological breakthroughs in large-scale farming might help farmers to be more effective and efficient in their production, however, at the end of the day, they might lead to more pollution pouring into Lake Erie, leaving more costs on the hands of governmental stakeholders.

But technological advancements in more effectively and efficiently monitoring phosphorous levels, treating water, manufacturing less-phosphorous detergents and fertilizers, more efficient fertilizer application on lands, and innovations in farming technologies to decrease tilling and harrowing, are only a few of the advancements which help lower phosphorous levels in Lake Erie. New research methods such as digital elevation models created by the LiDAR technology, assists Lake Erie stakeholders to decide more informatively on topics such as flood mapping, areas of soil erosion risk identification, and precision agriculture (anonymous interviewee #1, personal communication, 2020).

Moreover, people are using far less water, because of all the technological innovations happening in home construction, such as low-water-use toilets and plumbing fixtures, appliances, and cloth washers (anonymous interviewee #1, personal communication, 2020).

The other technological variable that might affect the system hugely, is leak detection technology. Currently, leakages in the distribution system account for about 17% of the extracted water (Statistics Canada, 2019). However, if this is enhanced, it can drastically influence the amount of water wasted, and at the end of the day, poured into rivers, as a non-point source, and without being treated.

These technological advancements can be of huge help to the local governments to decrease their costs, and to lessen their dependency on more budget from the higher-level authorities. Since these technological advances lessen costs for local governments, they can be considered as a buffer for the negative economic factors discussed in the previous section as well.

5.3.8.5. Environmental Issues

In several spring seasons of the past few years, floodwaters have spilt over western Lake Erie's beaches and ran down on the nearby streets, parking lots, and homes neighbouring the beaches. This has been, and is predicted to be, an ongoing issue with all the Great Lakes, as a result of the increase in melting snow and heavy rains in the recent years (Armenakis and Nirupama, 2014).

These floodwaters are one of the many consequences of an uncontrollable environmental variable, climate change, which is changing the dynamics of Lake Erie's system. Climate change causes higher spring and summer temperatures, and with it, less ice cover, more evaporation, and thus, bigger storms, and increasing water levels result. These effects cause serious damages to lakefront property owners, recreational boating, and commercial shipping companies. Floodwaters also increase costs for Regions and Cities in regards to many service areas such as water treatment and distribution (McNeil, 2019).

Moreover, ice storms might also hugely damage distribution infrastructure all around cities. Water main breaks and similar incidents have seen increases in number in the recent years, because of ice storms, which have also increased during the recent weather changes (Armenakis and Nirupama, 2014).

Increasing blooms also result in loss of fish and wildlife habitats, which in turn, increases invasive species such as white perch, and zebra and quagga mussels, which costs businesses of the region, commercial and sport fishing opportunities and natural and cultural heritage. Moreover, the increase of these invasive species in Lake Erie, pushes phosphorous closer to the shores of Lake Erie, increasing blooms more than ever before. This situation causes clogging at water intakes (drinking and industrial), which requires more budget to collect water from water resources, and to treat the low-quality collected water (Shin, 2013; TidesCanada, 2015).

The other environmental shock that could change the current system's dynamics, is a huge contamination of some sort, should it affect the Great Lakes, especially Lake Erie, in enormous scale. Another possible shock might be that the regional rivers pouring into any of the Great Lakes, are contaminated. This can also hugely affect cities in the Great Lakes' watersheds, since they would require alternative water sources to provide for their residents, and businesses in the region (anonymous interviewee #2, personal communication, 2020).

As mentioned in the insights provided for the 1970s, the local governments can initiate awareness and educational initiatives to convince the higher-level authorities that environmental changes require attention, and thus, more authority and budget to deal with.

5.3.8.6. Multivariable External Factor: The Water Efficiency Master Plan

As mentioned in the previous sections, Canada's population is growing substantially, not only in the bigger cities such as Montreal, Vancouver, and Toronto, but also in medium-sized cities. The increase in population, combined with limited resources, triggers many managerial concerns for federal, and provincial governments, and regional and local Municipalities. And water, as a limited natural resource, has always been one of the central points of discussion among key stakeholders such as governments, businesses, NGOs, and the society at large.

All the aforementioned issues apply to the Region of Waterloo as well, in which the population is growing fast, and water sources are limited. Thus, the Region, and Municipalities have been focusing their attention on developing more effective water conservation strategies to prevent these two variables (population growth, and water limitation), from negatively affecting the stakeholders.

One of the main initiatives which the Region developed, is the Water Efficiency Master Plan (WEMP). It was initially approved in 1998, to reduce water consumption by 1.5 million gallons per day in 10 years (i.e. by 2009). The WEMP was revised several times to incorporate more efficient methods such as a subsidized rain barrel distribution program, a revised Water Conservation By-Law, and increased public education (Gombos, 2014).

WEMP, has historically achieved significant water savings (up to 42% ahead of the target for 2011, and exceeding the water consumption goal of the 2015 WEMP). Although these initiatives reduce costs, and contribute to the deferral of large water infrastructure projects, the population growth has been more than projected, and this necessitates further enhancement to the currently planned programs (Gombos, 2014).

For example, Great Lakes Pipeline construction was proposed as an option to secure water for the Region. Lake Erie was proposed as a pipeline source in part because there's already a water-taking permit in place that's enough to provide water for the Waterloo Region and other communities. The Ontario government approved the permit in the 1970s, to pipe water from Lake Erie to Waterloo Region. However, the Ministry of the Environment mentioned that it will reject Lake Huron as a source, to prevent water being extracted from one Great Lakes and poured into another. Water extracted from Lake Huron would get used in Waterloo, and then it would pour into Lake Erie as wastewater (The Waterloo Record, 2007). This move from one lake to the other would violate current treaties (e.g. the Great Lakes-St. Lawrence River Basin Water Resources Compact) (Saeger, 2007).

Regional government discussed pipeline construction from Great Lakes to be initiated by 2035, when the population would grow beyond 729,000 people. Environmentalists oppose a pipeline at any time or at any cost. They try to advertise focusing instead on conservation and groundwater protection (The Waterloo Record, 2007).

However, given the significant cost of this project as a large capital project, the government preferred to focus on other low-cost methods such as water conservation measures, education and awareness initiatives, and thus, the Water Supply and Distribution Master Plan recently deferred the pipeline project to 2051, and it claims that this saves amounts reaching up to 100 million dollars for the taxpayers and around 77,000 tons of CO_2 emissions. Of course, this is conditioned on water consumption averages decreasing from around 200 liters, to about 170 liters per capita per day (Gombos, 2014).

The program will ensure that the Region of Waterloo continues to be an innovative leader in water efficiency. The current water efficiency program is broad and comprehensive, and has already achieved deep market penetration in several areas because of its maturity – notably with low-water toilet rebates and rainwater barrel sales. There is a need now to put forward creative and innovative programming to reach beyond the "low hanging fruit" (Gombos, 2014).

All said, the Water Efficiency Master Plan (WEMP) is a variable which does not only fit in the Political and Legal category of the PESTLE model, but can also be investigated as a technological, economic, and environmental factor, which affects all stakeholders including local, provincial, and federal governments in both US and Canada, businesses, NGOs, and the society as a whole. This plan hugely affects the dynamics of the Lake Erie system, and thus, the local governments should be closely monitoring its effects on future arising disputes among the relevant stakeholders.

Chapter 6 Conclusions: Summary, Contributions, Limitations, and Future Research

6.1. Summary

This study is an attempt to better understand the relationships among water resource stakeholders which are directly or indirectly affected by the Great Lakes. Each of these stakeholders have different preferences and options they can choose from, and this brings about disputes and conflicts which can become serious and complicated in some cases. This study presents methods and a framework that can be used to avoid or to mitigate the impacts of future conflicts. Toward this purpose, the following steps are taken in this thesis.

Initially, an introduction to the various stakeholders of the Great Lakes was provided. Decisionmakers such as different governmental levels, various businesses, NGOs, and communities surrounding Great Lakes and their stakes in the Great Lakes water management system, as a globally unique fresh-water resource, were investigated. Then, the different types of potential conflicts among these stakeholders were discussed.

Some of this information was extracted from interviews with knowledgeable individuals currently or previously working in one or more of the involved stakeholders / institutions. This step carried its own challenges regarding finding, and setting meetings with, insightful individuals in different associations relevant to the Great Lakes. The other information pieces were gathered through relevant media articles, journal papers, website pages, documentaries, and other secondary sources. All of these enhanced our understanding of the stakeholders, their options and preferences, and the existing and future conflicts.

In the next step, in the knowledge gap section of the 2nd Chapter, the need of a holistic view to resolving the Great Lakes' complex conflicts was discussed. It is only with a holistic perspective that the complex interrelated conflicts and also the various uncontrollable external variables could be studied in one single, interdependent (and somewhat simplified) system.

In the next chapter (Chapter 3), the methodology phases of this thesis are laid out in more detail. Causal loops, GMCR, external and scenario analysis, are the main introduced methods combined and used for achieving the aforementioned holistic perspective. Causal loops diagrams provide a visual and analytical view of the interactions among all the relevant variables affecting the Great Lakes water management system. And the GMCR, helps us in thoroughly investigating conflicts among the involved stakeholders. Finally, external and scenario analysis, shed light on the uncontrollable shocking factors affecting the stakeholders' options and their actions' consequences. The methodology section concluded with a detailed description of the data collection processes conducted in this thesis.

Chapter 4 focused on two disputes as case studies to showcase a few of the complex and interrelated conflicts among the discussed stakeholders in more detail. For example, powerful and ambitious water bottling companies, and other heavy water consumers, seek more access to the Great Lakes water sources, increasing the rate of exhaustion of the Great Lakes. But multiple adjoining states and provinces, and a number of NGOs which initiate various events, conferences, and other initiatives, are factors in opposition with the previously mentioned stakeholders. These Protectors as we called them, try to protect the water source from threatening water extractions. The different options and preferences of these opposing decisionmakers, causes a dynamic system in which each of their actions, affects the other decisionmaker's status, and available moves. At the end of each of the two conflict analysis case studies, through mathematical analysis of the cases, an equilibrium state is identified. This state introduces a situation in which both decisionmakers stop moving.

Chapter 5 investigates another complex case. The reason this case was focused on was that it has been an ongoing conflict among the stakeholders for decades. And thus, linking them from different time periods (to discuss the aforementioned holistic perspective) could be showcased better. In Chapter 5, the condition of rising phosphorous levels in Lake Erie was studied in two different times, the 1970s and also 2010s. As was seen in the results, not only were the stakeholders different in these two times, but their successors' options and preferences changed during the 40-50-year period in between.

In the first insight section of the 5th Chapter (section 5.3.7), it was discussed that if the local-level governments were aware of the external variables occurring after 1970s, they would have been able to adapt to the situation sooner, and in a more effective manner, which would have enabled them to end up in a more preferred position in 2010s. Similarly, in Section 5.3.8, the external variables in 2010s are focused on, suggesting that the authorities can enhance their position in the future, through investigating these variables and adapting to the changing system dynamics.

In sum, the vitality of the Great Lakes ecosystem to various Canadian and U.S. stakeholders, and the threats that have loomed over the sustainability of this essential environmental asset, necessitate considerable efforts, such as this thesis, to map and to mitigate or resolve the numerous complicated conflicts among the involved stakeholders.

6.2. Contributions

The analyzed cases in this thesis are only the tip of the iceberg of existing disagreements among numerous Great Lakes stakeholders. As mentioned in the Introduction (Chapter 1) and Literature

Review (Chapter 2) of this thesis, these conflicts range from water extraction disputes (e.g. between Waukesha City and Other Municipalities, or between Nestle and City of Guelph), to water distribution and water treatment disagreements (Lake Erie pollution concerns). Other potential disputes, in addition to shocks due to uncontrollable external variables that might occur, further complicate the conflict resolution process. Therefore, comprehensive research on the complex multiphase disputes among the stakeholders must be conducted to understand the conflicts with a broader perspective and in one framework instead of investigating them as separate independent instances.

This is the reason that in this thesis, the past, present, and future of conflicts were investigated, instead of only focusing on one time period. Initially, the causal loop, the GMCR method, and external analysis were applied to the Lake Erie pollution conflict in the 1970s. This first step served as a background investigation for the main conflict analysis period, which was the 2010s. The GMCR of 2010s was based on results from the previous conflict analysis implemented for 1970s. Moreover, the future of the conflict was investigated through external analysis which depicted the many potential futures for the involved stakeholders.

The holistic framework presented in this thesis can help the relevant stakeholders understand and mitigate the interrelated and successive conflicts that occur over water resources in the Great Lakes and the rivers flowing into them. For example, as mentioned in Section 2.4.7 (Regional and Local Water Utilities' Fragile Position in Conflicts), water utility providers carry a huge responsibility towards millions of water users. The framework proposed here can especially help these water utility providers to predict, and better yet, to prevent potential water disputes with other stakeholders. This could save money and time for not only the utility providers, but also other stakeholders through lessening bureaucratic costs and energy put on lobbying efforts, or other potential complications in their relations among each other. It can also improve quality of life for the people living in the Great Lakes region through increasing collaboration among the main decisionmakers in the Great Lakes water management system.

6.3. Limitations and Challenges

6.3.1. Anonymity in the Interview Process

Similar to any other research project, this thesis has also undergone many challenges. Although many of these challenges were successfully dealt with when conducting the research, some other were structural limitations stemming from the nature of this thesis topic.

For example, this thesis focuses on conflict among water management systems stakeholders. And not surprisingly, when initiating and conducting the interviews, some of the interviewees had concerns about their identities being known publicly throughout and after the research took place. An extra effort had to be employed to ensure the interviewees and the UW ethics office, about the anonymity of the interview process. Throughout the interviews, sensitive topics were avoided by some of the interviewees. For example, questions about disputes between Regions and Municipalities were approached with caution by some interviewees, even though a thorough process had taken place to keep their identities undisclosed. Preventing discussion of certain topics in depth, has most certainly affected the quality of the current research, since some aspects of the system dynamics might have been missed due to the interviewees' concerns about anonymity.

6.3.2. Corona Virus Challenges

Another obstacle in the face of conducting this research, was the occurrence of the Corona pandemic. On 12th of March 2020, a while after interviews for this research had been initiated, University campuses and many other governmental and businesses closed their physical locations, and almost all activities were forced to be done remotely through online channels. This put a huge restriction regarding networking initiatives for finding potential interviewees, and also, research which could have been conducted at these institutions' libraries or offices. A number of interviews were also cancelled due to the additional workload imposed on the interviewees, and the fact that they became too busy with their other commitments during this transition to working remotely.

6.3.3. Subjectivity in Model Development

As discussed previously, identifying and sorting the feasible states in a proposed Graph Model is a complicated and to some extent, a subjective procedure based on the opinions and judgments of the researcher and the sources used in the data collection phase of the research. To overcome this concern, sources with different perspectives were chosen to provide an unbiased view of the conflicts in interest. Moreover, as mentioned in the Methodology section of the thesis (Chapter 3), the interviewees who were invited to participate, were selected from different backgrounds and institutions, which represented multiple conflict stakeholders. This ensured different perspectives to be considered when developing causal loops, GMCR models, and analyzing external variables in the environment.

6.4. Future Research

6.4.1. Achieving More Objectivity

In hopes of achieving more objectiveness in the Graph Model development process, the various Great Lakes conflicts should be investigated by other authors as well. Comparing the results obtained on all of the conducted studies enhances our understanding of the effects each author's perspective has on modeling and analyzing of the conflicts.

6.4.2. Perceptual Graph Model

The Graph Model analysis is an effective technique to investigate complex conflicts and their decisionmakers' options and preferences. However, this approach does not take into account the perceptions these decisionmakers have towards each other.

Emotions and perceptions towards the other stakeholders (either positive or negative) have the potential to transform feasible states to infeasible states or vice versa. Thus, some states might be added or removed from the analysis because of these perceptions among the stakeholders. As an exaggerated example, in the Israel-Palestine conflict, the existing anger and prejudice among the involved decisionmakers eliminates the prospect of peaceful resolutions, triggering aggressive attitudes. In other words, because of their emotions toward each other, some states are hidden in their perspectives. The Perceptual Graph Model method has been introduced in the literature to fill this gap (Obeidi, Hipel, & Kilgour, 2005).

In Perceptual Graph Models, unique stability analyses for each of the decisionmakers are conducted. And through a complex mathematical approach, these inconsistent perspectives of the decisionmakers towards each other, are combined into one single analysis. The Perceptual Graph Model technique provides both individual and overall stability analyses. Therefore, the final stable equilibria states are investigated under more solution concepts and perspectives, and thus, are more robust since they represent a broader range of stability in different situations and from different viewpoints.

It is recommended that in the future studies on Great Lakes disputes, the Perceptual Graph Model technique be also used. Through this approach, emotions that might have been developed among the decisionmakers of the system would be investigated, assisting in better understanding and also in providing resolutions for these disputes. This method can also contribute to studying the conflicts in an interrelated manner, linking together the stakeholders and their conflicts in time, and in different fields of disagreement.

6.4.3. Thematic Analysis

A common method used to analyze qualitative material such as interviews is thematic analysis. This method focuses on identifying and analyzing meaningful patterns within the gathered qualitative data. The primary and secondary data collected in the research data gathering phase, are coded into different categories, and then, into broader themes. These themes are then combined into models through theoretical interpretations.

As mentioned in the previous section, the COVID-19 pandemic prevented more interviews to take place in this project. However, more interviews with previous and current representatives of all the relevant decisionmakers in the disputes, will help this research to become less biased, and more thorough. And analyzing all these interviews using other effective qualitative methods such as thematic analysis, can provide in-depth insight, and enhance our understanding of the dynamics of the water management system.

6.4.4. Corona Virus as a Multivariable External Factor

An external variable, which has taken place in the latter phases of conducting this research, is the pandemic of COVID-19, namely, Coronavirus. The Virus single-handedly changed the face of the world. Within weeks of its appearance, the pandemic closed public schools, universities, and many governmental institutions, such as Regions and Municipalities, to encourage social distancing, as a strategy to stop or slow down the spread of the Virus.

The whole pandemic started back in December 2019 from a wild animal local market in Wuhan, a city in China. After a few months (February 2020), the Virus was all over the globe, infecting more than 55.6 million people, with more than 1.34 million deaths to date (20th of November 2020). In Canada, the Virus has infected 316,000 people, with 11,265 deaths up until now (20th of November 2020). These numbers still growing, forced many countries, including Canada, to announce multiple differently structured quarantines in the country, enforcing people to stay inside (Jackson and Connolly, 2020).

From the confirmation of the first case in Waterloo Region on 5th of March 2020 (Nielsen, 2020a), there has been many closures or drastic changes of schedules in many governmental operations, from airports, provincial offences courts, recreation facilities, libraries, museums, and child cares, to City facilities, and water efficiency programs such as rain barrel distribution programs, or leakage auditing initiatives. Budgeting, infrastructure development, revenue generation, operations management, and almost all components of governmental institutions at all levels, have and will face changes, in light of this uncontrollable external variable (Nielsen, 2020b).

Governments have reallocated their budgets to initiatives protecting businesses which are vulnerable to being damaged by the pandemic. Moreover, only in Ontario, $3.3 billion was put aside to support frontline health care workers and to increase hospital capacity, including $2.1 billion in new and urgent funding to combat and contain the spread of COVID-19. With this new funding, Ontario added 1,000 acute care and 500 critical care beds. Ontario also announced possible partnerships with hotels to free up beds in hospitals and 72 COVID-19 assessment centres opened across the province to help with this fight against the Virus (Government of Ontario, 2020d). All of this drastically changed environment, has a shocking effect on Great

Lakes' stakeholders including, but not limited to, businesses, different levels of the government, NGOs, and the society as a whole.

The pandemic, as an external variable, has also affected water usage, and wastewater level patterns, which in turn, influences local, regional, provincial, and federal governments. Municipalities' revenue levels have been affected as well (Government of Ontario, 2020d).

All said, the pandemic has yet to unfold the vast influences it has started to put on different industries, institutions, and the society as a whole. A lot of research has to be dedicated to understanding how the spread of COVID19 has affected the world in political, economic, social, technological, legal, and environmental categories. Local governments have to proactively investigate the drastic changes this pandemic has caused in their regions' water management systems, and act accordingly to enhance their position in the system dynamics.

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Appendices

Appendix A Interview Forms

Appendix A.1. Consent Form

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by **Professors Carl T. Haas,** and **Mark Knight,** and PhD student, **Sevda Payganeh** of the Department of Civil and Environment Engineering at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher. I am also aware that it is not possible to withdraw the interview data, after papers have been submitted.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#41121). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions contact Sevda Payganeh at spaygane@uwaterloo.ca ,Carl Haas (Faculty Supervisor; PhD,Civil and Environmental Engineering,University of Waterloo) at 1-519-888-4567 x35492 or chaas@uwaterloo.ca, or Mark Knight (Faculty Supervisor; PhD,Civil and Environmental Engineering, University of Waterloo) at 1-519-888-4567 x36919 or mark.knight@uwaterloo.ca.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐YES ☐NO

I agree to have my interview audio recorded.

☐YES ☐NO

I agree to the use of anonymous quotations in any thesis or publication that comes of this research.

☐YES ☐NO

Participant Name: ______________________________ (Please print)

Participant Signature: ______________________________

Witness Name: __________________________________ (Please print)

Witness Signature: ________________________________

Date: ______________________________

Appendix A. 2. Information Letter

Title of the study: Great Lakes Regional Water Conflicts Analysis

Faculty Supervisor: Carl Haas, PhD, Civil and Environmental Engineering, University of Waterloo. Phone: 1-519-888-4567 x35492, Email: chaas@uwaterloo.ca

Faculty Supervisor: Mark Knight, PhD, Civil and Environmental Engineering, University of Waterloo. Phone: 1-519-888-4567 x 36919, Email: mark.knight@uwaterloo.ca

Student Investigator: Sevda Payganeh, MSc, Civil and Environmental Engineering, University of Waterloo. Email: spaygane@uwaterloo.ca

To help you make an informed decision regarding your participation, this letter will explain what the study is about, the possible risks and benefits, and your rights as a research participant. If you do not understand something in the letter, please ask one of the investigators prior to consenting to the study. You will be provided with a copy of the information and consent form if you choose to participate in the study.

What is the study about?

You are invited to participate in a research study about government institutions, businesses, NGOs and other stakeholders relevant to the Great Lakes water resources. More specifically, the purpose of the study is to find out what each of these stakeholders think about the Region of Waterloo Water Efficiency Masterplan Program (WEMP). Does the Masterplan fulfill their preferences? How are each of these stakeholders affected by the Masterplan? And what can be done to provide better options for each decisionmaker?

This study is being undertaken as part of my (Sevda Payganeh) PhD research.

I. Your responsibilities as a participant

What does participation involve?

Participation in the study will consist of participating in an interview (face-to-face or online through video-chat, based on your preference). The session is expected to last 60-90 minutes. A light snack and refreshments will be provided. The interview will be held in an office at the University of Waterloo, or at a place of your choosing, at a time and date convenient for you. I will guide a discussion on Great Lakes Water Management Systems, especially the question of Region of Waterloo Water Efficiency Masterplan Program (WEMP) stakeholders' preferences and options. The types of questions that I will ask include: Who might the Water Efficiency Masterplan Program (WEMP) affect? What benefits and risks does it bring to the different stakeholders?

With your permission, the session will be audio-recorded to ensure an accurate transcript of the interview. With your permission, anonymous quotations may be used in publications and/or presentations. You will have the option of going through the transcript after the interview has been transcribed.

Who may participate in the study?

Individuals who are informed about the Great Lakes, especially Lake Erie, and the Region of Waterloo Water Efficiency Masterplan Program (WEMP), are potential interviewees of the current study.

II. Your rights as a participant

Is participation in the study voluntary?

Your participation in this study is voluntary. You may decide to leave the study at any time by communicating this to the interviewer. Any information you provided up to that point will not be used. You may decline to answer any question(s) you prefer not to answer. You will also have the option of going through the interview transcript after the interview has been transcribed. You can request your data be removed from the study up until February 2020 as it is not possible to withdraw you data once my thesis has been submitted.

What are the possible benefits of the study?

Participation in this study may not provide any personal benefit to you. I hope the data from the interview increases our understanding of the Great Lakes and their stakeholders relationships.

What are the risks associated with the study?

Please be aware that should you decide to participate in an online interview, information is transmitted over the internet and thus, privacy cannot be guaranteed. There is always a risk your responses may be intercepted by a third party (e.g., government agencies, hackers). University of Waterloo researchers will not collect or use internet protocol (IP) addresses or other information which could link your participation to your computer or electronic device without first informing you.

Other than this, there are no known or anticipated risks associated with participation in this study. If a question, or the discussion, makes you uncomfortable, you can choose not to answer. See above for more details on voluntary participation.

Will my information be kept confidential?

Your identity will be kept confidential. Identifying information will be removed from the transcripts and the audio recordings will be deleted after I defend my thesis (expected to be summer 2020). The transcripts and other electronic data will be retained for a minimum of 7 years, after which they will be destroyed. Data will be stored in an encrypted folder on my password protected laptop. Only the research team will have access to study data. No identifying information will be used in my thesis or any presentations or publications based on this research.

Once all the data are collected and analyzed for this project, I plan on sharing this information (without identifying anyone in particular) with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please provide your email address, and when the study is completed, anticipated by May 2020, I will send you the information.

Questions, comments, or concerns

Has the study received ethics clearance?

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE# 41121). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

Who should I contact if I have questions regarding my participation in the study?

For all other questions contact Sevda Payganeh at spaygane@uwaterloo.ca ,Carl Haas (Faculty Supervisor; PhD, Civil and Environmental Engineering, University of Waterloo) at 1-519-888-4567 x35492 or chaas@uwaterloo.ca, or Mark Knight (Faculty Supervisor; PhD, Civil and Environmental Engineering, University of Waterloo) at 1-519-888-4567 x36919 or mark.knight@uwaterloo.ca

Appendix A.3. Recruitment Email

Hello,

My name is Sevda Payganeh, and I am a PhD student working under the supervisions of Professor Carl Haas, and Professor Knight in the Civil and Environmental Engineering Department at the University of Waterloo.

You were introduced by my supervisors to take part in a University of Waterloo research study to gain information on Great Lakes, especially the Region of Waterloo Water Efficiency Master Plan (WEMP), as we are conducting a study that investigates how this plan is affecting the relevant stakeholders.

Participation in this study involves a 60-90 minute face-to-face (in-person or Skype) interview which discusses the topic more in detail. I would like to assure you that the study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee.

However, the final decision about participation is yours.

The following time slots are available to participate in this study.

- …
- …
- …
- …
- …

If you are interested in participating, please contact me at spaygane@uwaterloo.ca and list your top three choices for when you would like to participate from the list above. Please also state you preferred method of interview (in-person or Skype or other video-chat platforms).

Sincerely,

Sevda Payganeh

Appendix A.4. Appreciation Email

University of Waterloo

Date

Dear ***(Name of Participant),***

I would like to thank you for your participation in this study entitled Great Lakes Regional Water Conflicts Analysis. The data collected during interviews will contribute to a better understanding of the Region of Waterloo's Water Efficiency Master Plan (WEMP) and its relevant stakeholders.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#41121). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions contact Sevda Payganeh at spaygane@uwaterloo.ca ,Carl Haas (Faculty Supervisor; PhD,Civil and Environmental Engineering,Universityof Waterloo) at 1-519-888-4567 x35492 or chaas@uwaterloo.ca, or Mark Knight (Faculty Supervisor; PhD,Civil and Environmental Engineering, Universityof Waterloo) at 1-519-888-4567 x36919 or mark.knight@uwaterloo.ca.

Please remember that any data pertaining to you as an individual participant will be kept confidential. Once all the data are collected and analyzed for this project, I plan on sharing this information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or would like a summary of the results, please provide your email address, and when the study is completed, anticipated by May 2020, I will send you the information. In the meantime, if you have any questions about the study, please do not hesitate to contact me by email or telephone as noted below.

Sevda Payganeh

University of Waterloo
Department

spaygane@uwaterloo.ca

Appendix B: Surveys

To understand the ongoing and potential conflicts among water management related stakeholders, a survey has been developed and will be sent to a number of professionals, and involved decisionmakers in the water management system. These include, but are not limited to the executives and employees of municipalities, heavy water consumers, and NGOs.

These surveys help us better understand these decisionmakers' perceptions of the industry, and identify and monitor major external trends which affect different sectors of the system. Overall, responses to the below questionnaire will shed light on the challenges facing each decisionmaker and thus, significantly increase our ability to investigate different scenarios, and propose win-win solutions for the current and possible future disputes.

Thesis Project Interview Questions – Sevda Payganeh

Questions on Waterloo Masterplan Stakeholders and the Conflicts Among them:

- Who might the Water Efficiency Masterplan Program (WEMP) affect? What benefits and risks does it bring to the different stakeholders?

- Could you discuss the dynamics among the stakeholders of the WEMP? Which of them have constructive relationships, and how do you think their relationships might change in the future?

- The official reports that are widely available, are written by the region or other governmental institutions, and mostly discuss the WEMP's benefits for all stakeholders. Risks and possible disadvantages have not been mentioned that much. Where else can we get access to other perspectives regarding the plan?

- The recommended activities for between 2015 and 2025, cost about 1 million CAD annually, but where does the budget come from? Answer: Taxpayer's pockets! Will this cause cold feet in the community to support WEMP? But then, the pipeline will also cost 100 million dollars with a budget from the taxpayers. Which of these two options more directly affect taxpayers?

- Does the WEMP put businesses under pressure to adapt to tighter and more costly regulations and standards? What can they do (and to whom should they) voice their concerns to, over these increased pressures?

- During the process of the WEMP being developed, was any department from the Region, not consent with the way the data for the report was being collected and analyzed?

- Was the final draft of the report read and confirmed by the different stakeholders affected by the WEMP?

Questions on Waterloo Masterplan Scenario Analysis:

- What occurrences might drastically affect the current stable state among the stakeholders in the Waterloo Masterplan conflict? These occurrences can be in categories such as political, environmental, economic, social, technological, and legal.

- How do any of these variables affect the relationships the stakeholders have with each other?

Interview Points:

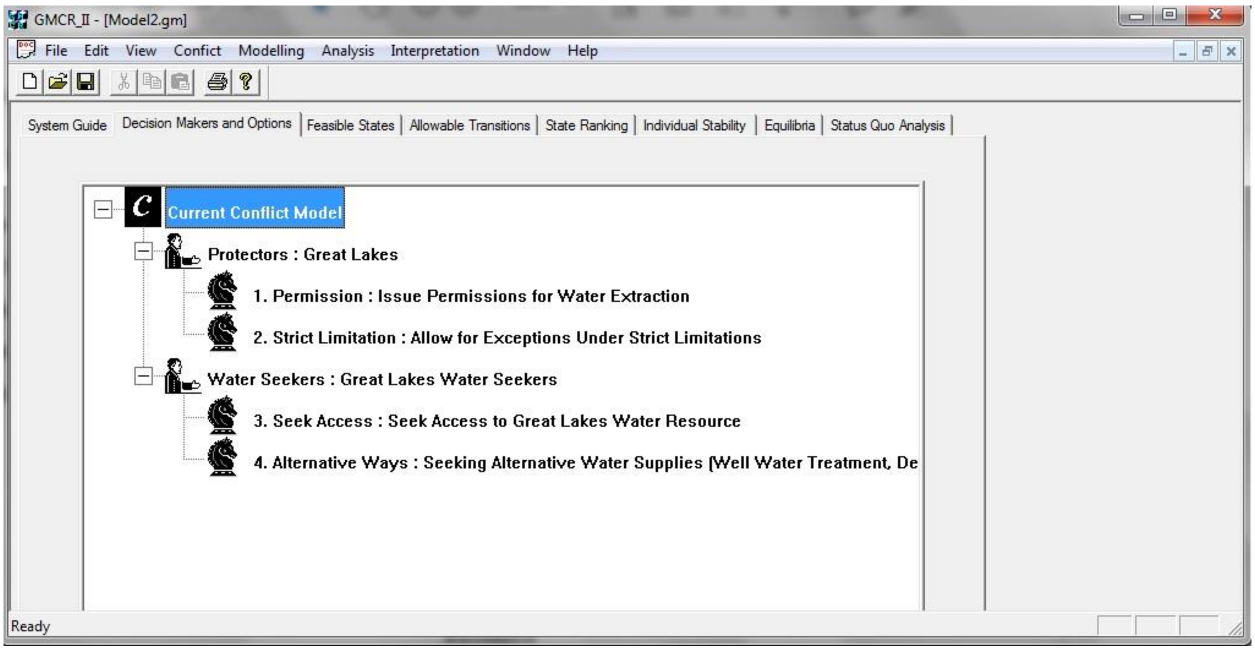
- Where can we find individuals or institutions which are not satisfied with the WEMP? And can we get them to sit with us in an interview?

Appendix C: GMCRII Screenshots (Case I)

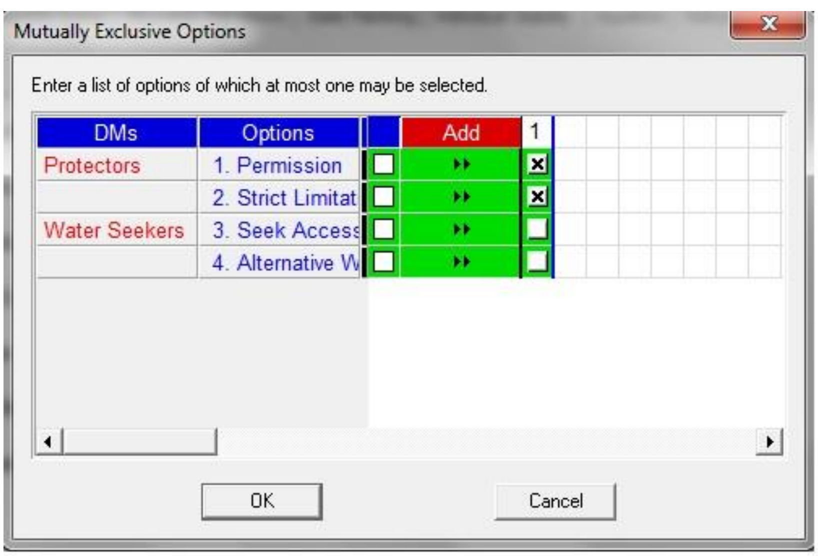
Note: All the below screenshots have been developed using the GMCRII decision support system (Fang et al., 2003a; Fang et al., 2003b; Hipel et al., 1997).

Note: In the below tables, “Y” is when the option is selected by the decisionmaker, and “N” is when the option is not selected by the decisionmaker.

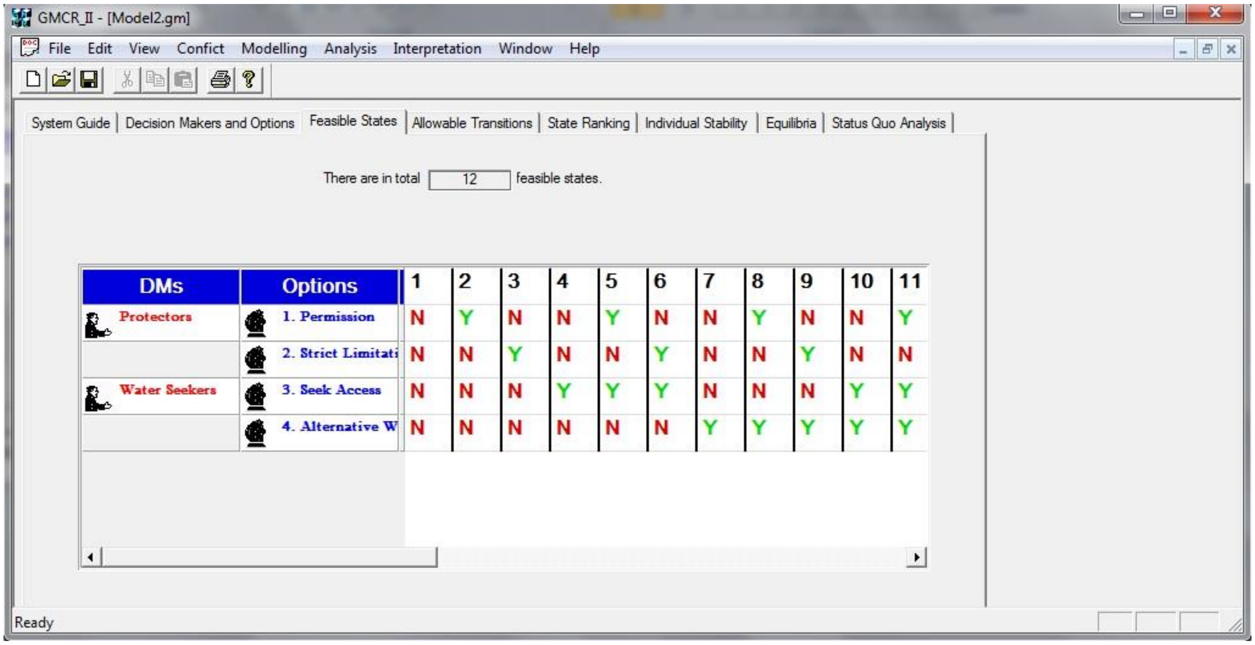
Appendix C.1. Decisionmakers and their Options



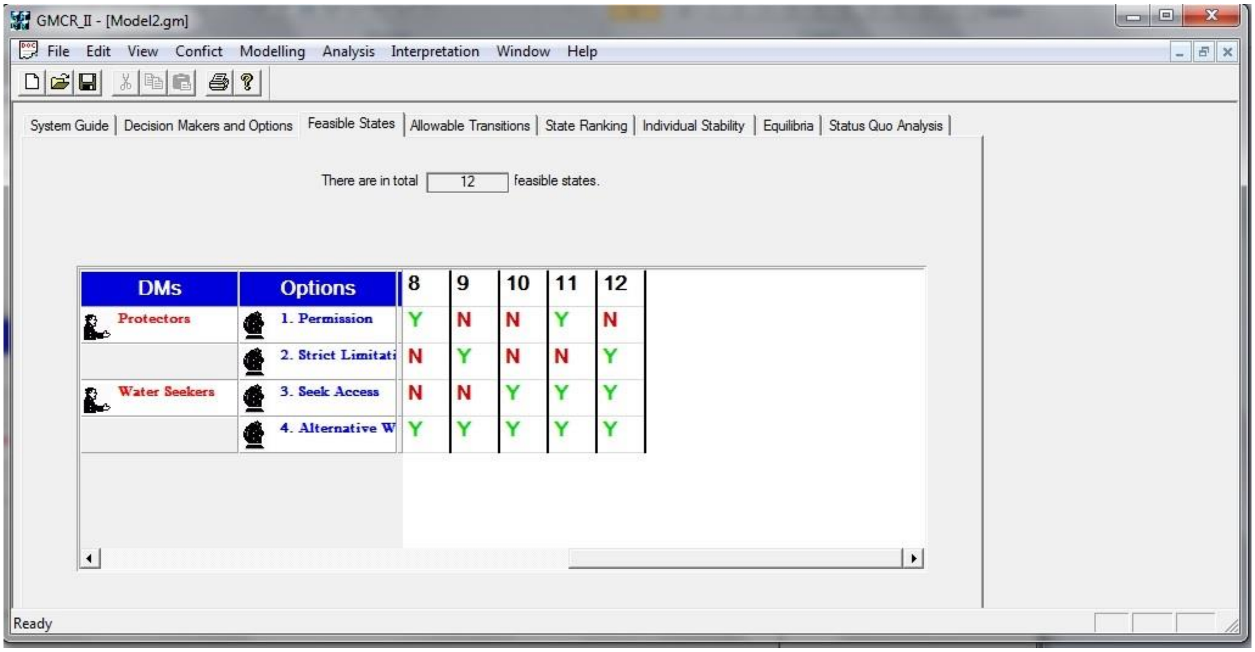
Appendix C.2. Determining Feasible States (Eliminating Infeasible States)



Appendix C.3. Feasible States

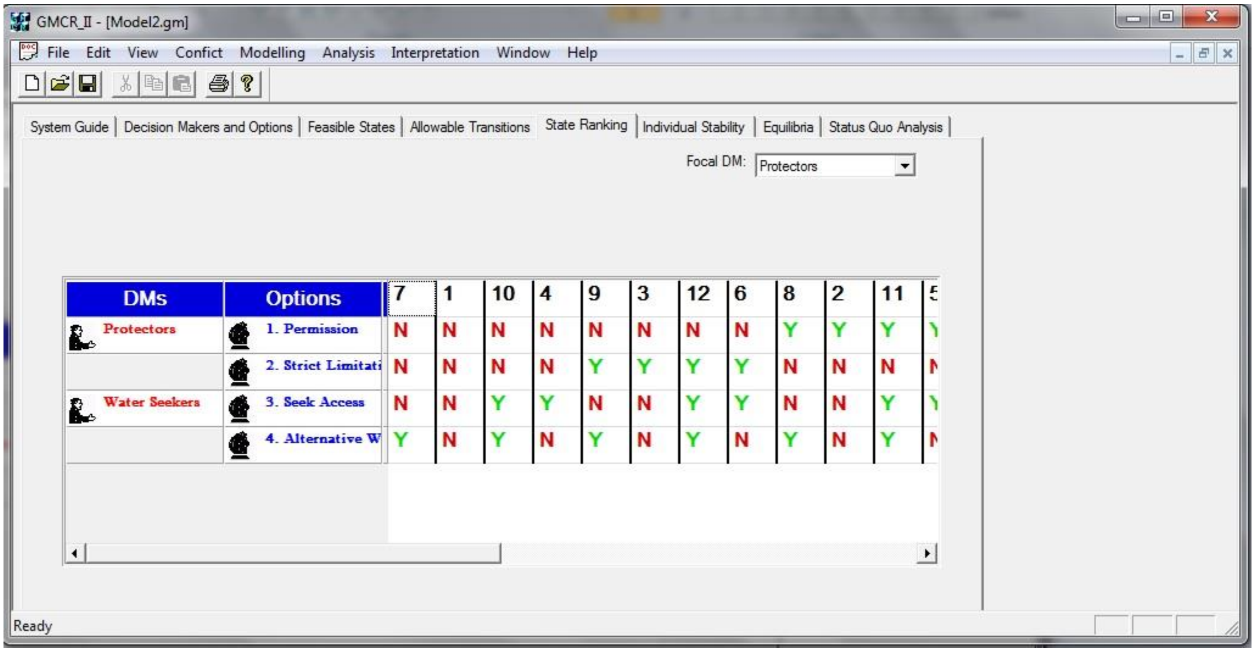


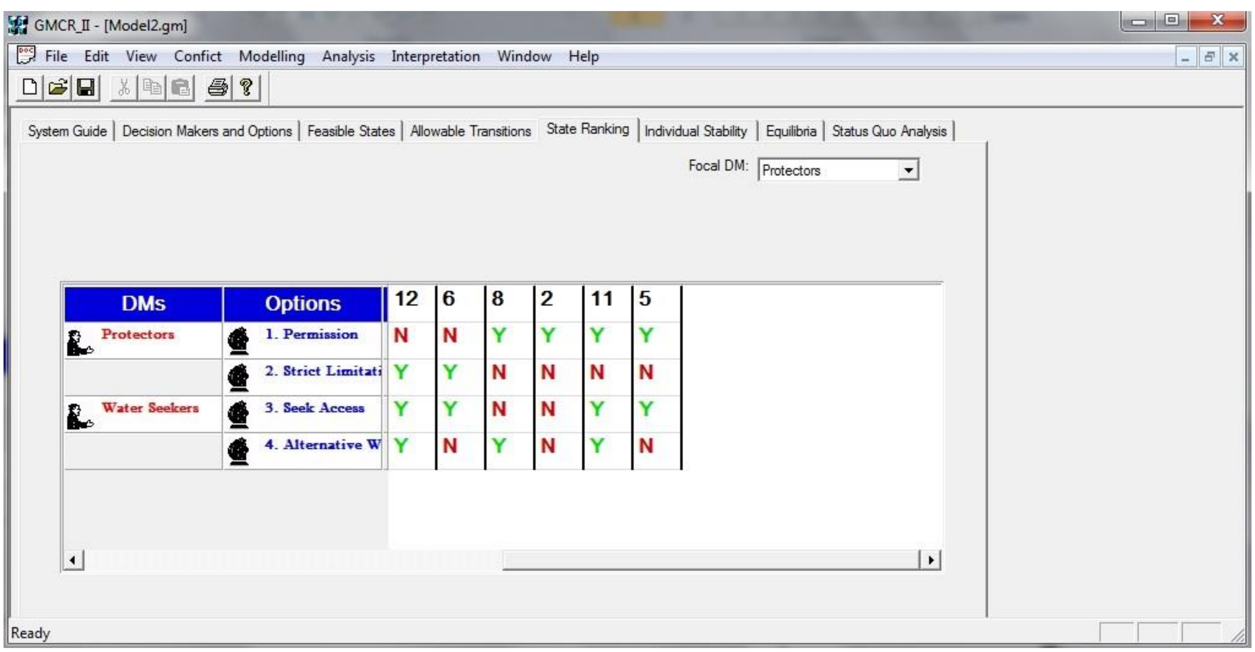
DMs	Options	1	2	3	4	5	6	7	8	9	10	11
Protectors	1. Permission	N	Y	N	N	Y	N	N	Y	N	N	Y
	2. Strict Limitati	N	N	Y	N	N	Y	N	N	Y	N	N
Water Seekers	3. Seek Access	N	N	N	Y	Y	Y	N	N	N	Y	Y
	4. Alternative W	N	N	N	N	N	N	Y	Y	Y	Y	Y



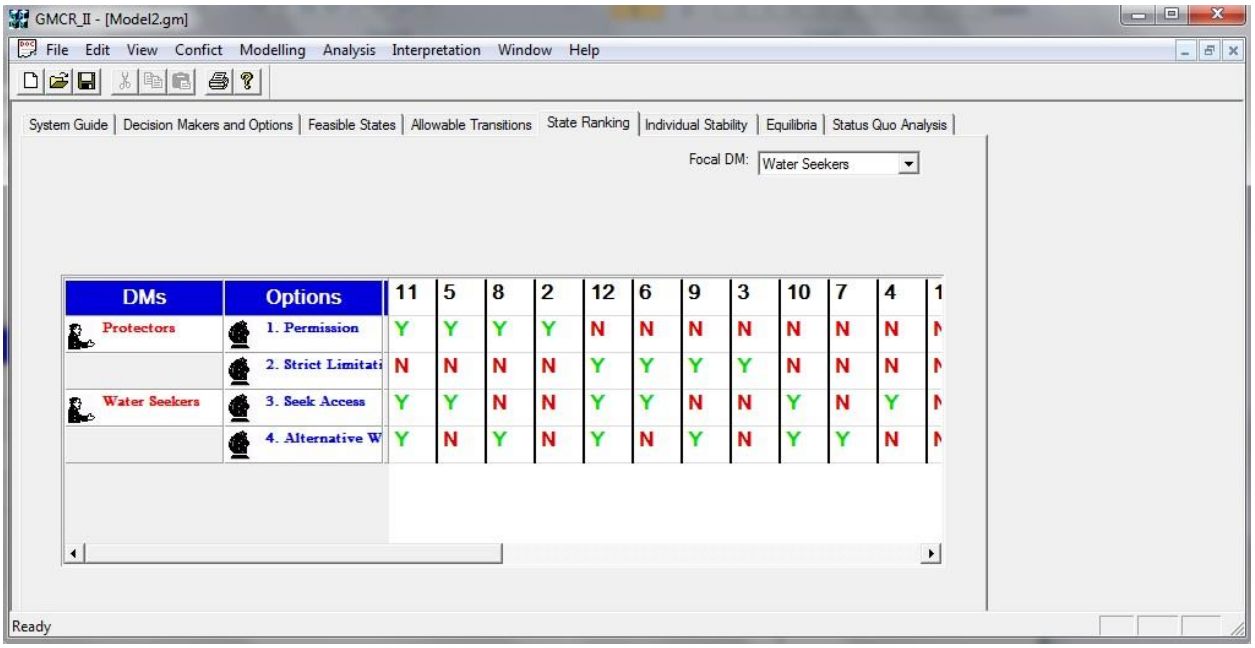
DMs	Options	8	9	10	11	12
Protectors	1. Permission	Y	N	N	Y	N
	2. Strict Limitati	N	Y	N	N	Y
Water Seekers	3. Seek Access	N	N	Y	Y	Y
	4. Alternative W	Y	Y	Y	Y	Y

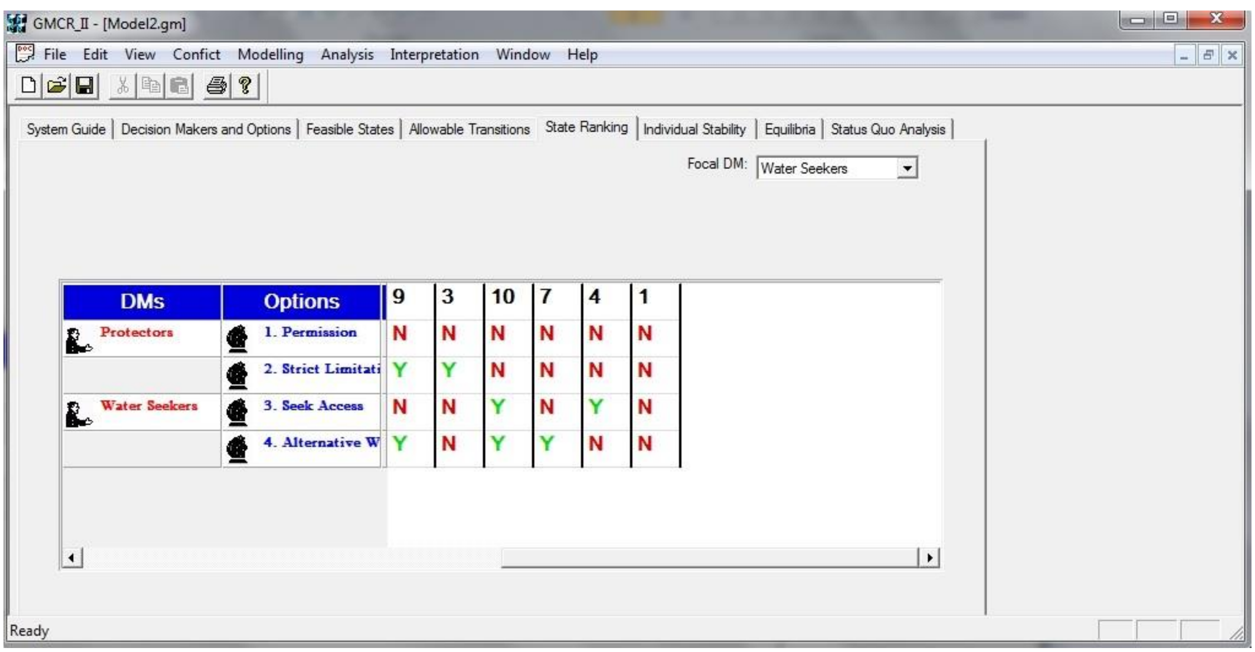
Appendix C.4. State Ranking (Preferences) for Protectors



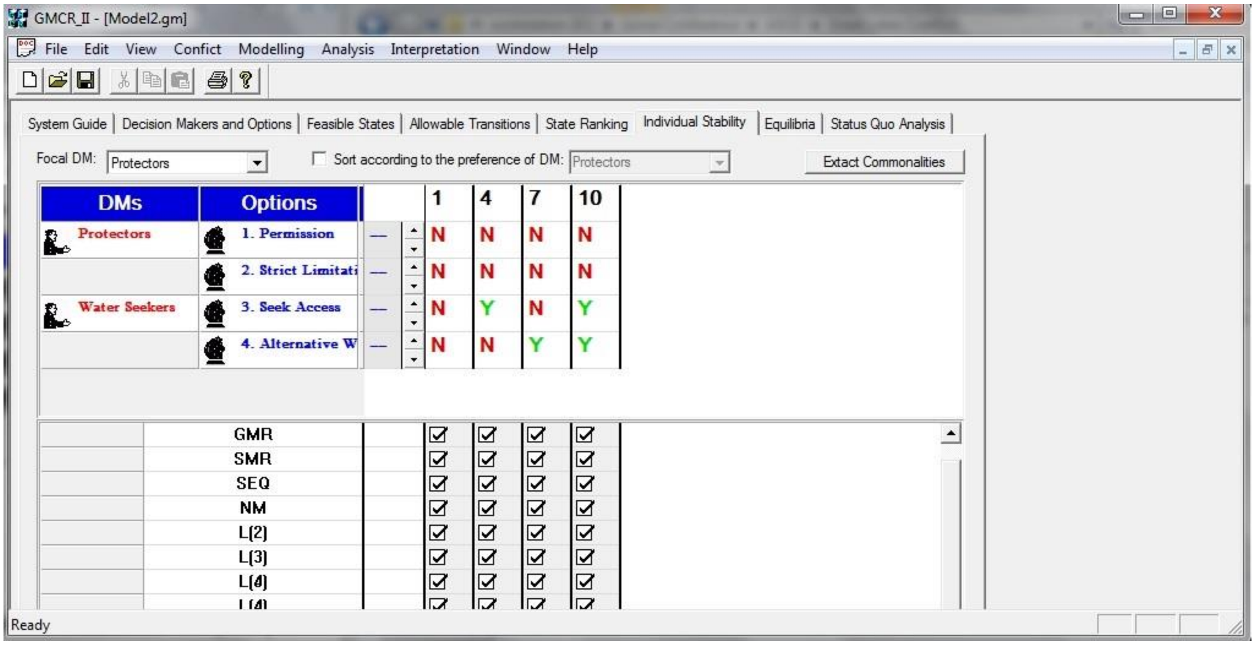


Appendix C.5. State Ranking (Preferences) for Water Seekers

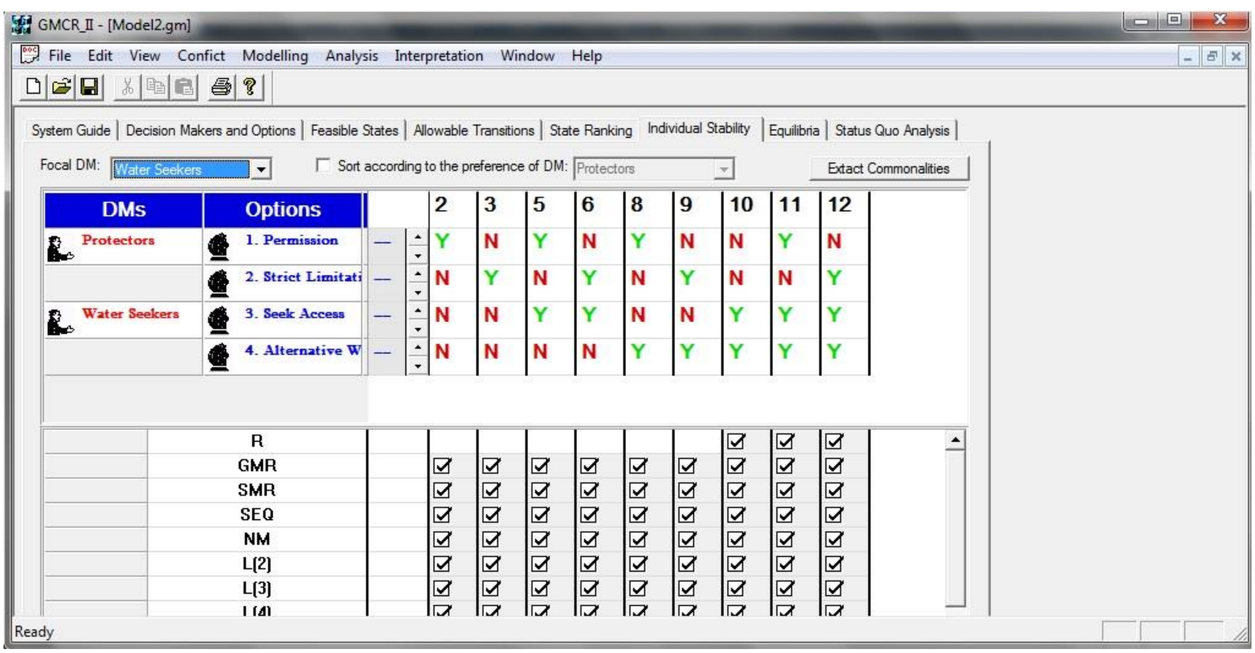




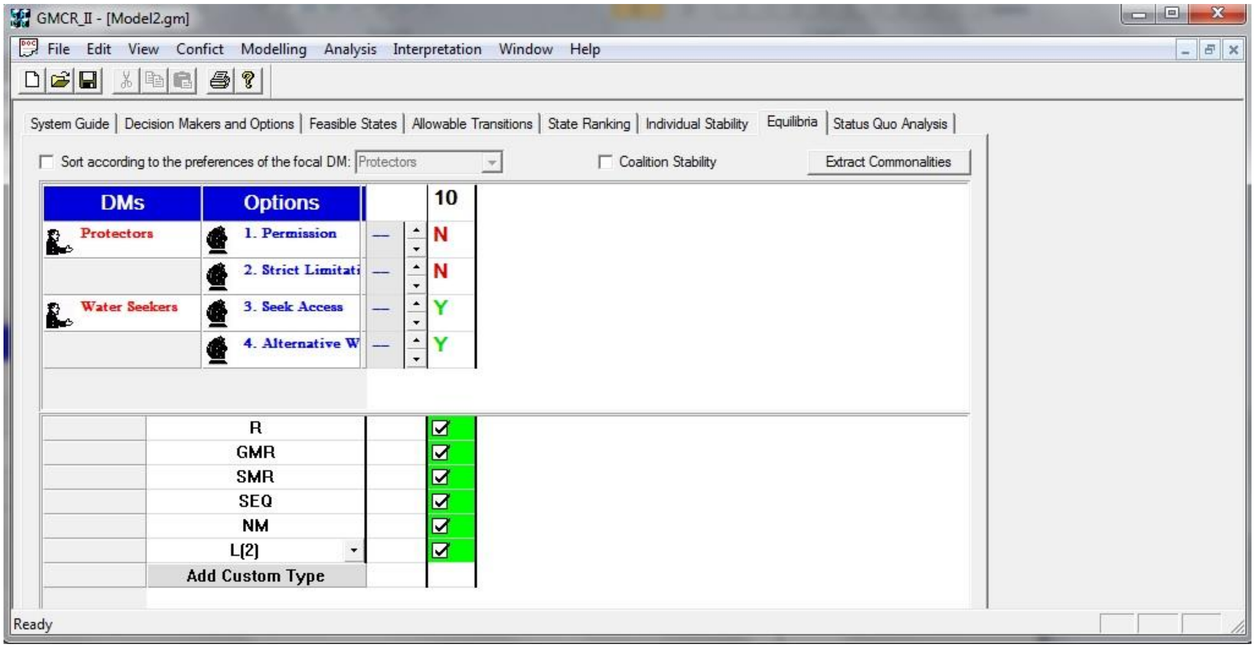
Appendix C.6. Individual Stability Analysis for Protectors



Appendix C.7. Individual Stability Analysis for Water Seekers



Appendix C.8. Equilibria (Stable State(s) for all Decisionmakers)

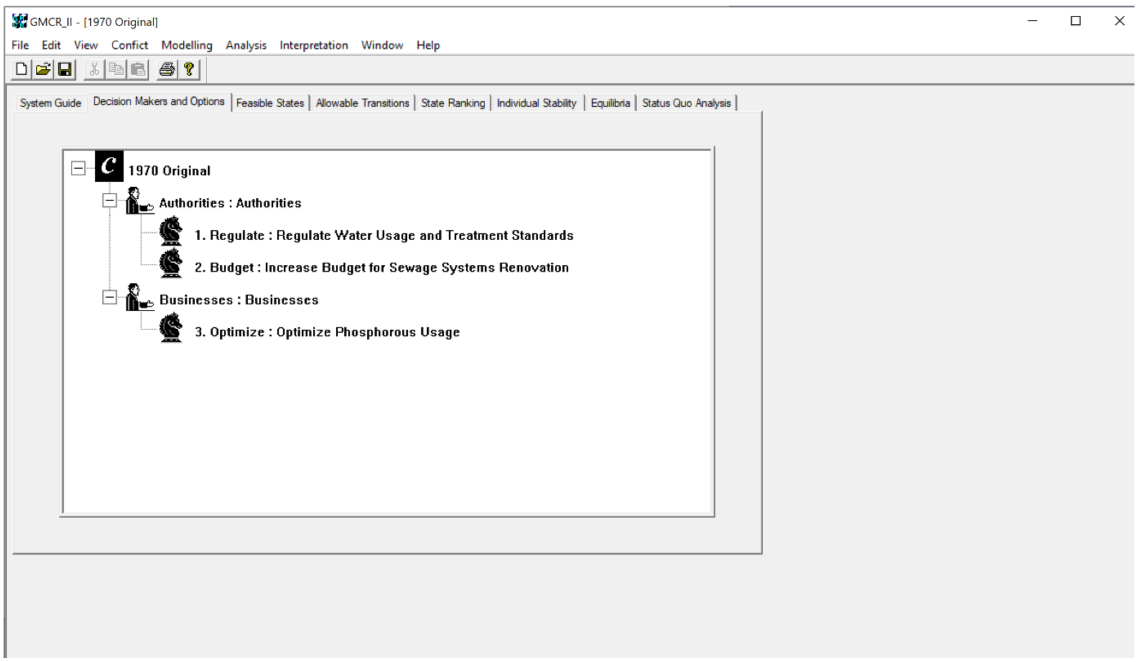


Appendix D GMCRII Screenshots (1970s)

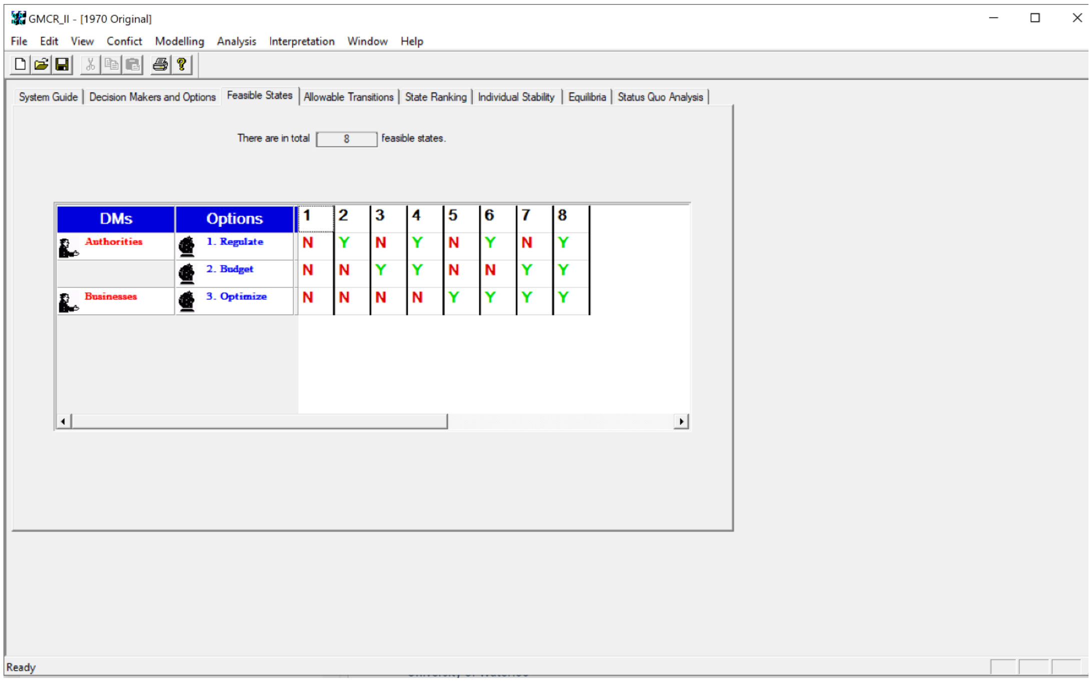
Note: All the below screenshots have been developed using the GMCRII decision support system (Fang et al., 2003a; Fang et al., 2003b; Hipel et al., 1997).

Note: In the below tables, “Y” is when the option is selected by the decisionmaker, and “N” is when the option is not selected by the decisionmaker.

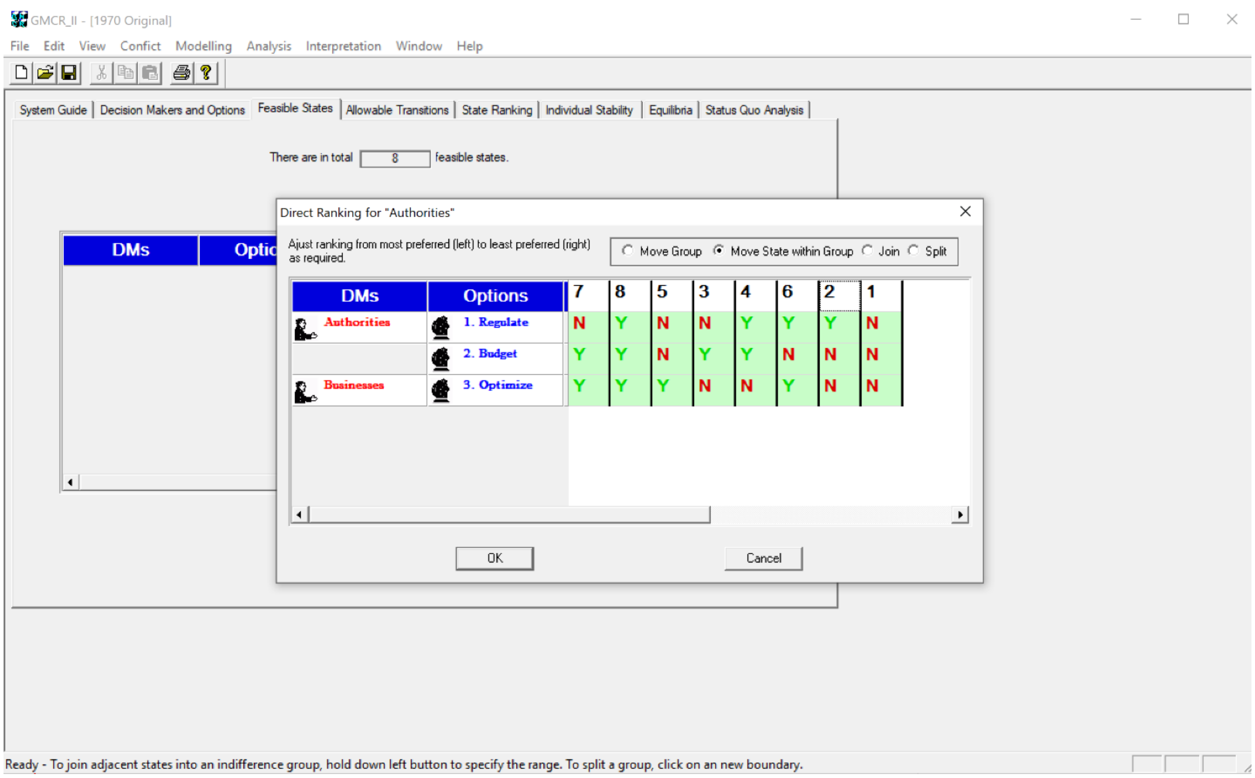
Appendix D.1. Decisionmakers and their Options



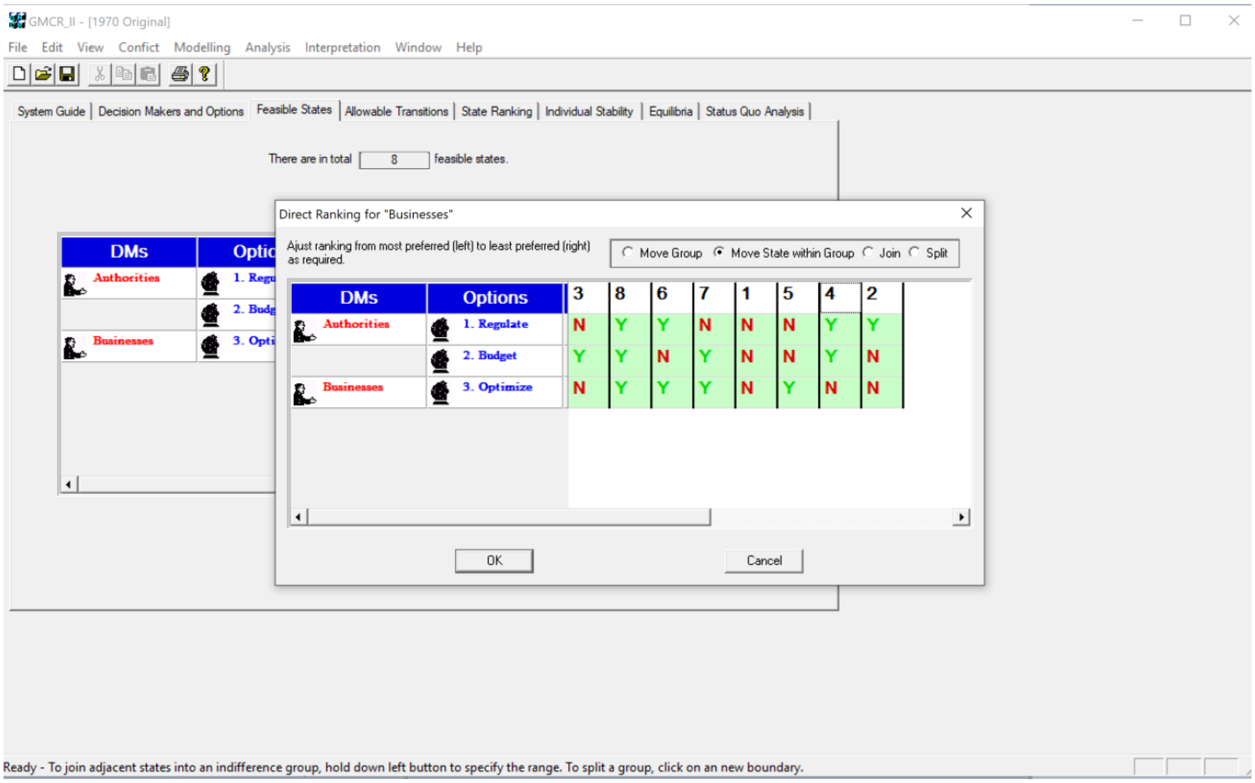
Appendix D.2. Determining Feasible States



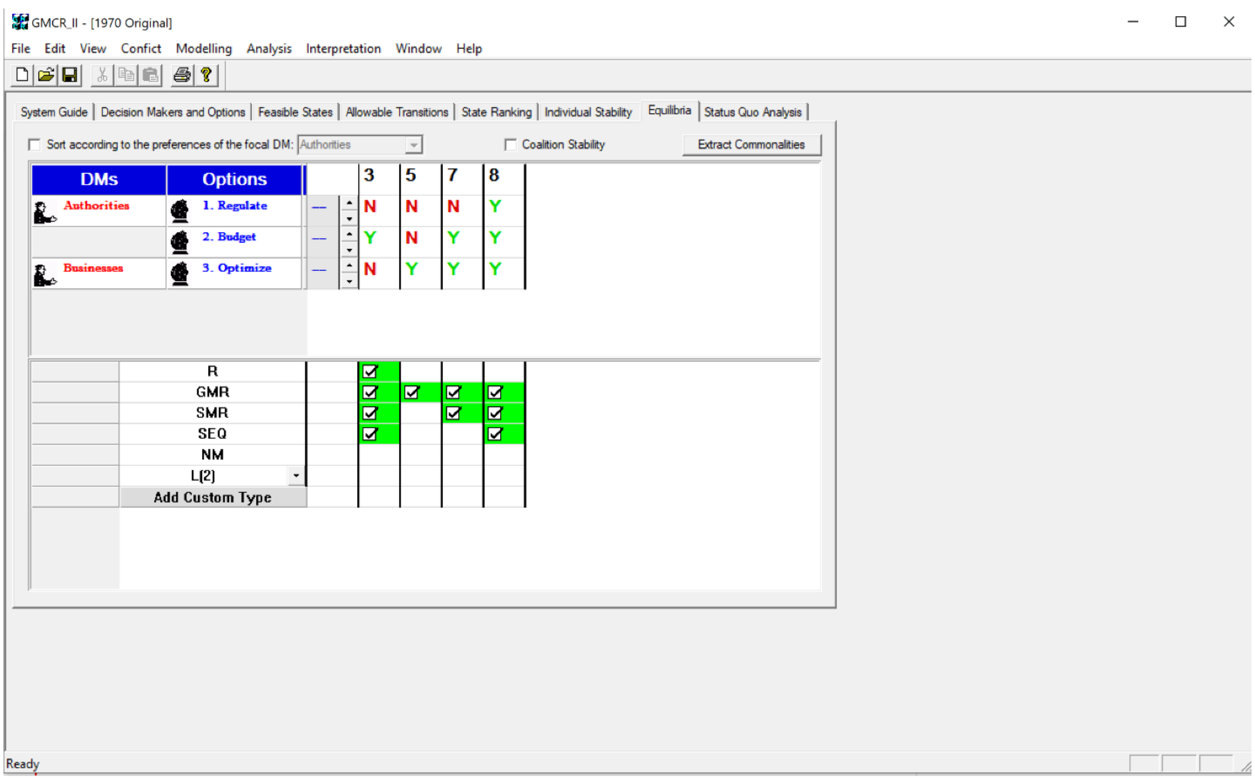
Appendix D.3. State Ranking (Preferences) for Authorities



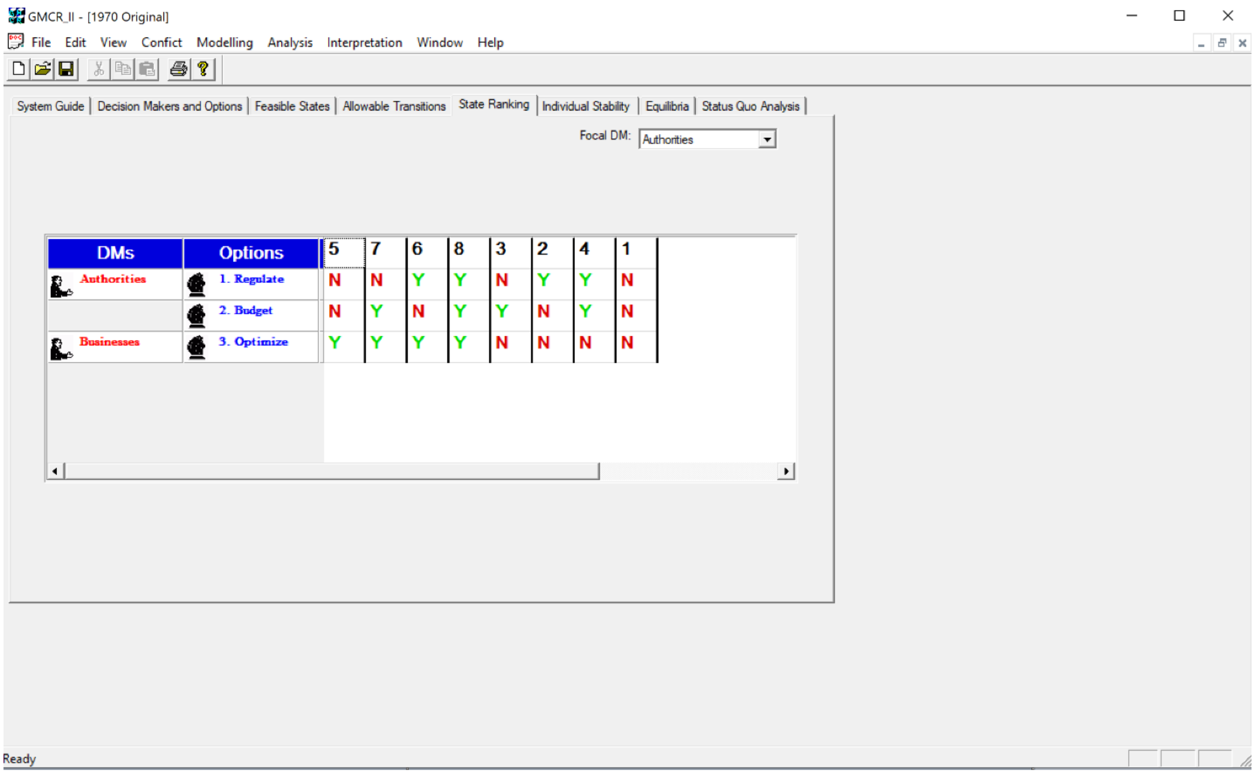
Appendix D.4. State Ranking (Preferences) for Businesses



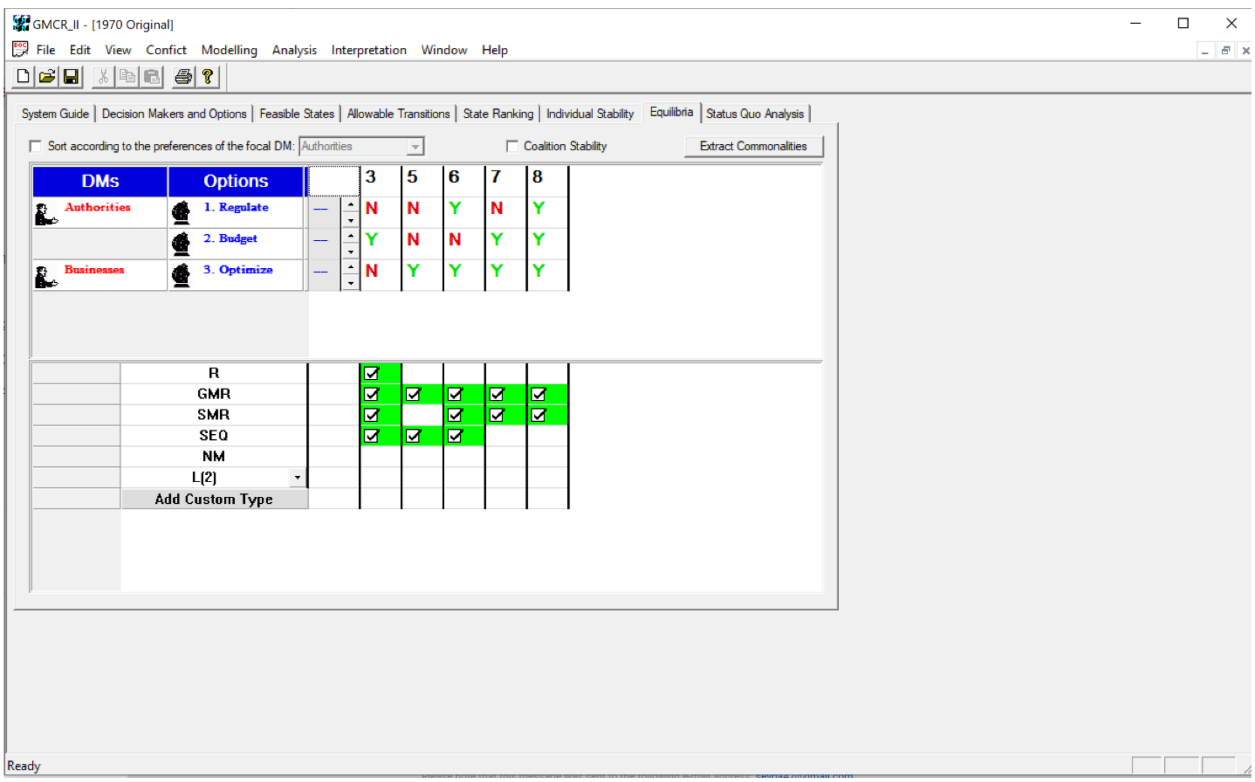
Appendix D.5. Equilibria (Stable State(s))



Appendix D.6 State Ranking (Preferences) for Authorities (Sensitivity Analysis)



Appendix D.7. Equilibria (Stable State(s)) (Sensitivity Analysis)

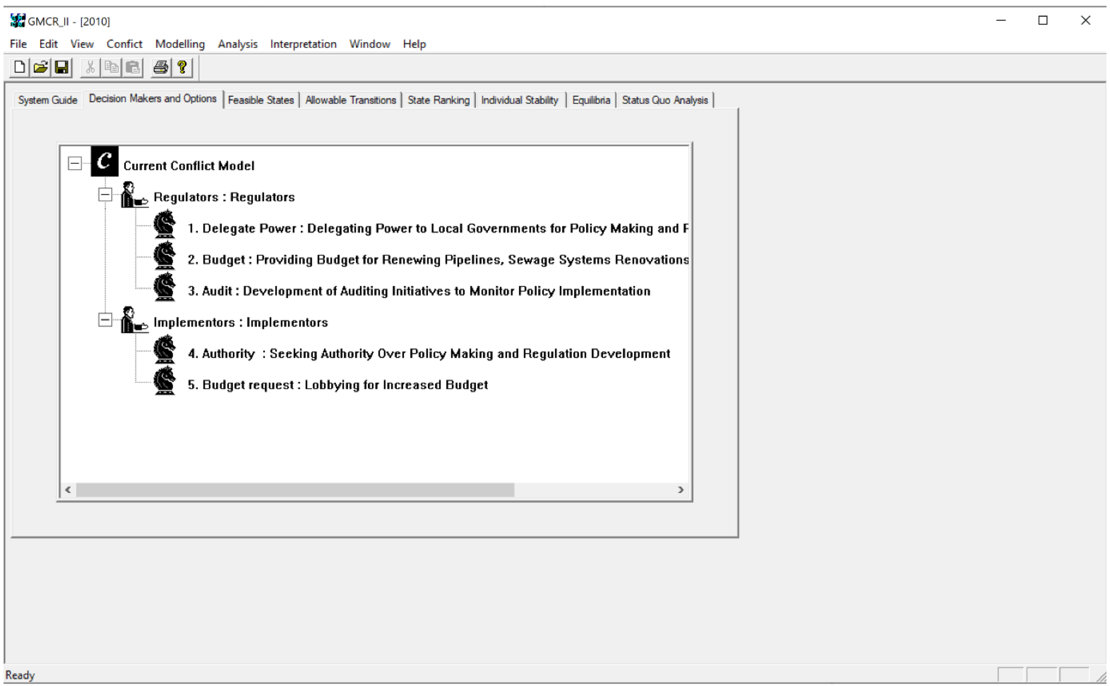


Appendix E GMCRII Screenshots (2010s)

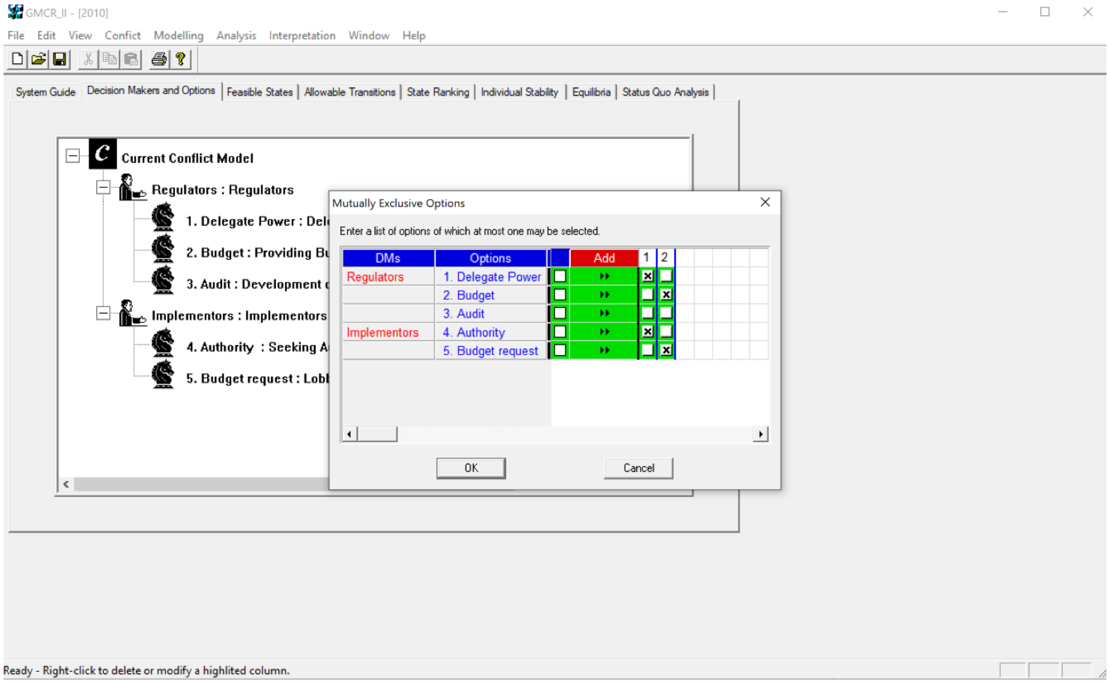
Note: All the below screenshots have been developed using the GMCRII decision support system (Fang et al., 2003a; Fang et al., 2003b; Hipel et al., 1997).

Note: In the below tables, “Y” is when the option is selected by the decisionmaker, and “N” is when the option is not selected by the decisionmaker.

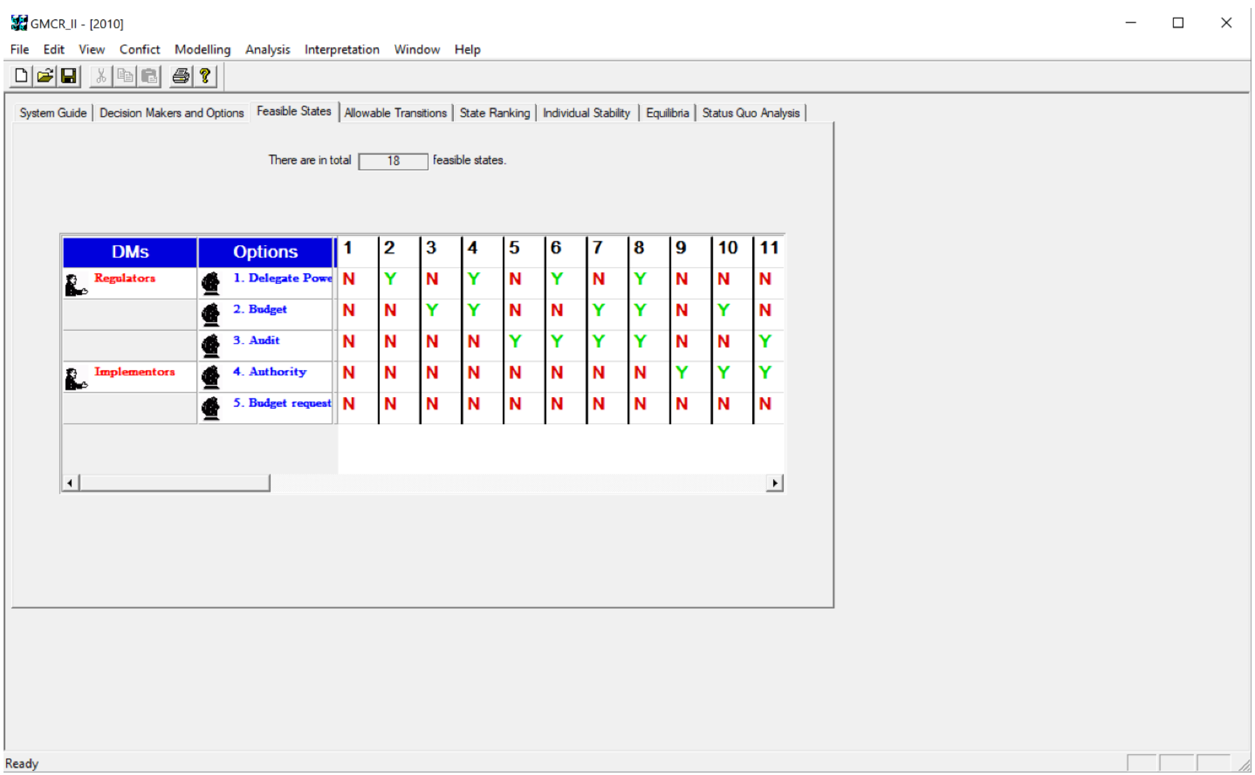
Appendix E.1. Decisionmakers and Their Options

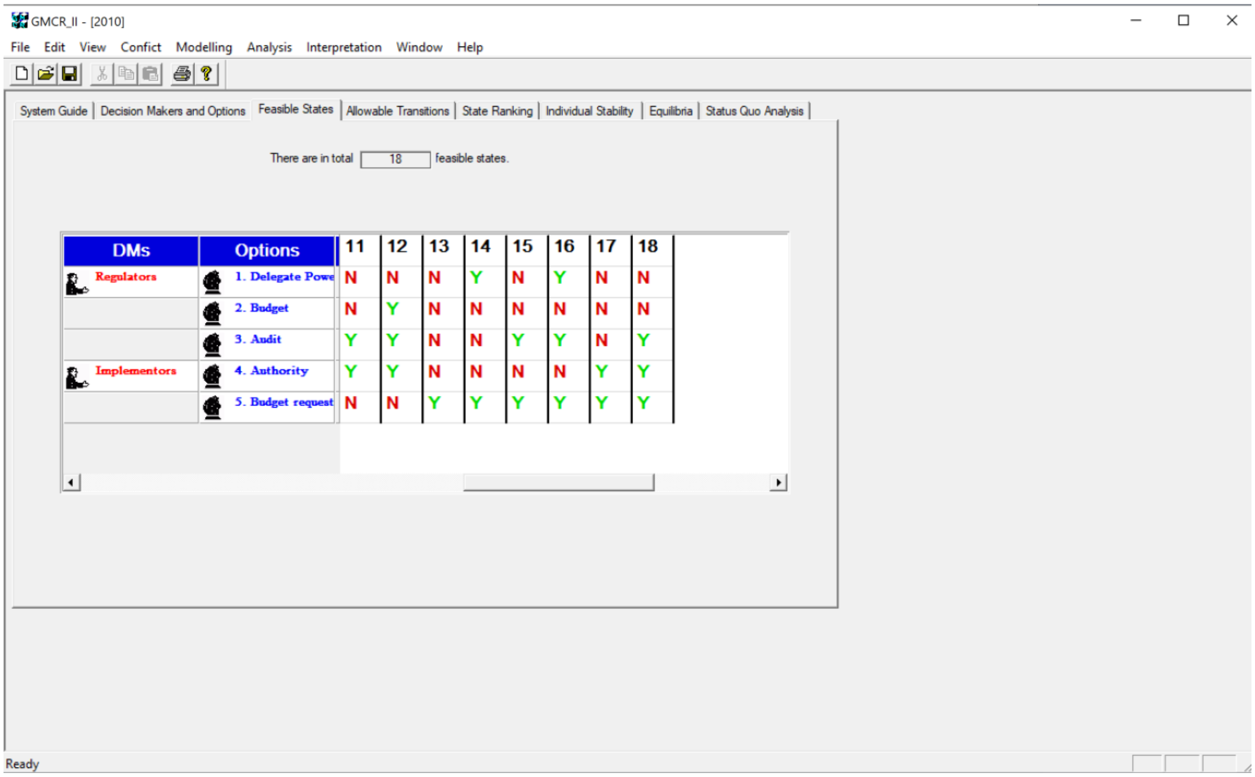


Appendix E.2. Determining Feasible States (Eliminating Infeasible States)

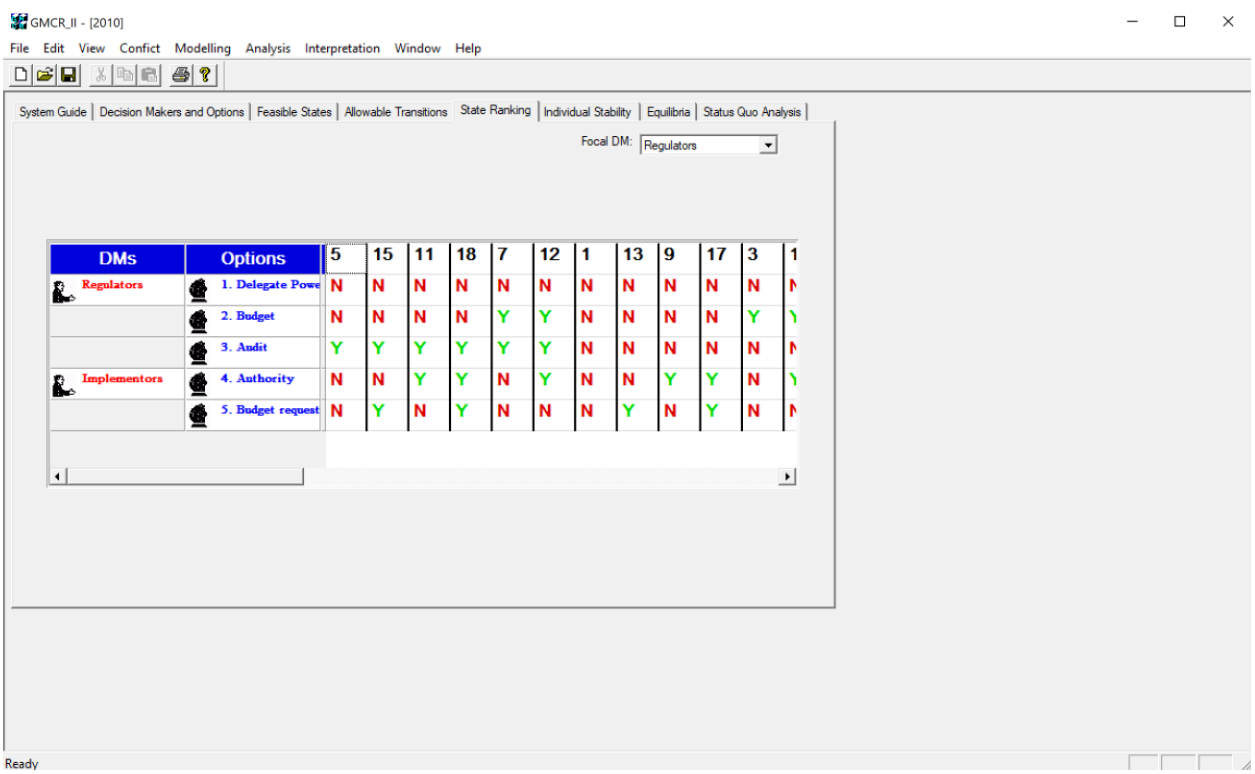


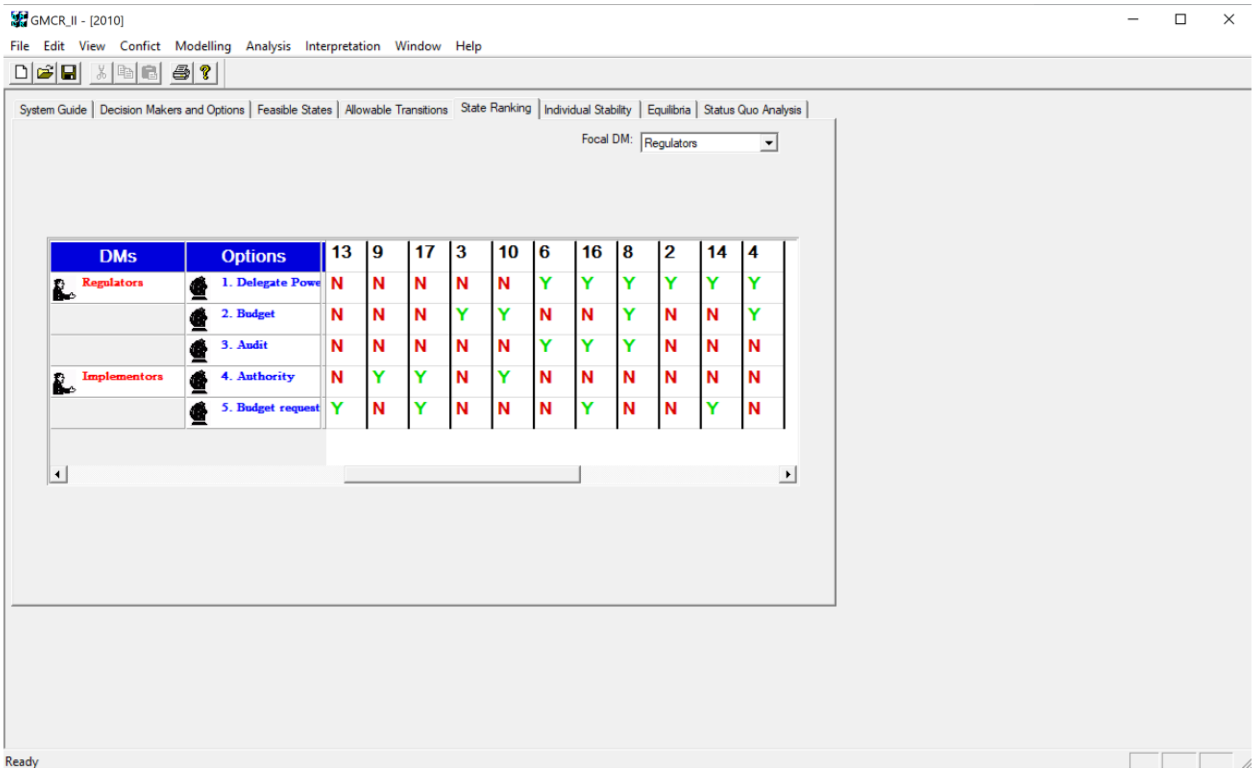
Appendix E.3. Feasible States





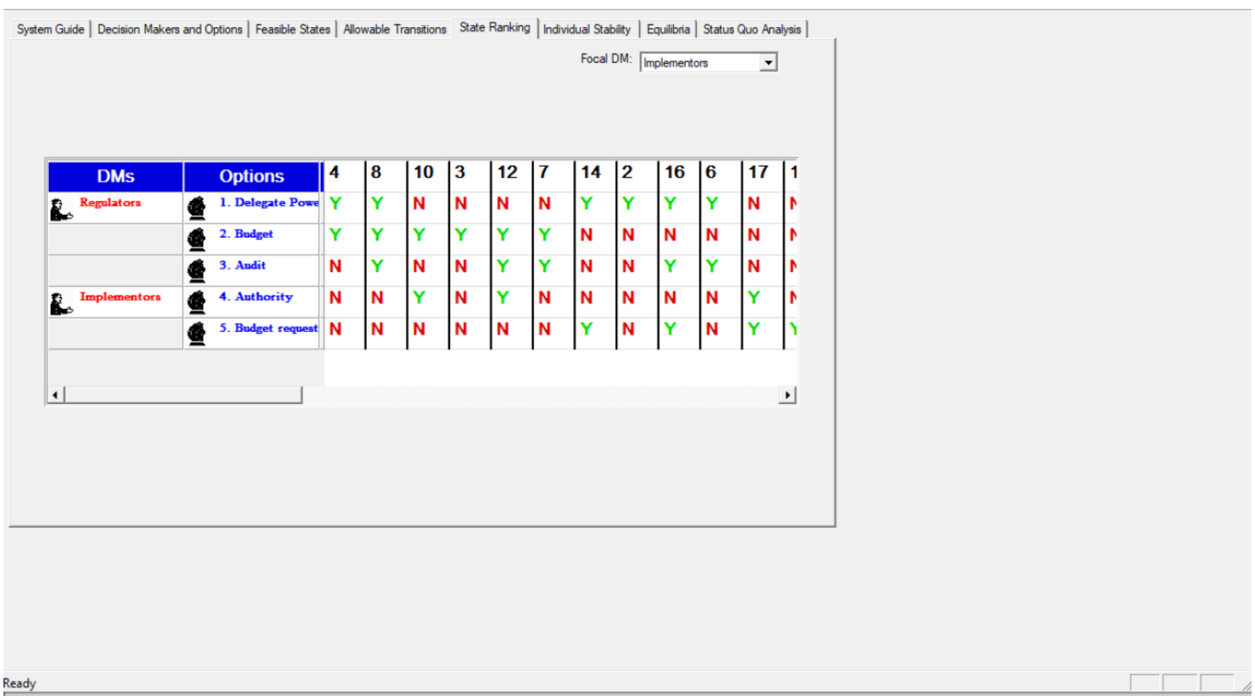
Appendix E.4. State Ranking (Preferences) for Regulators



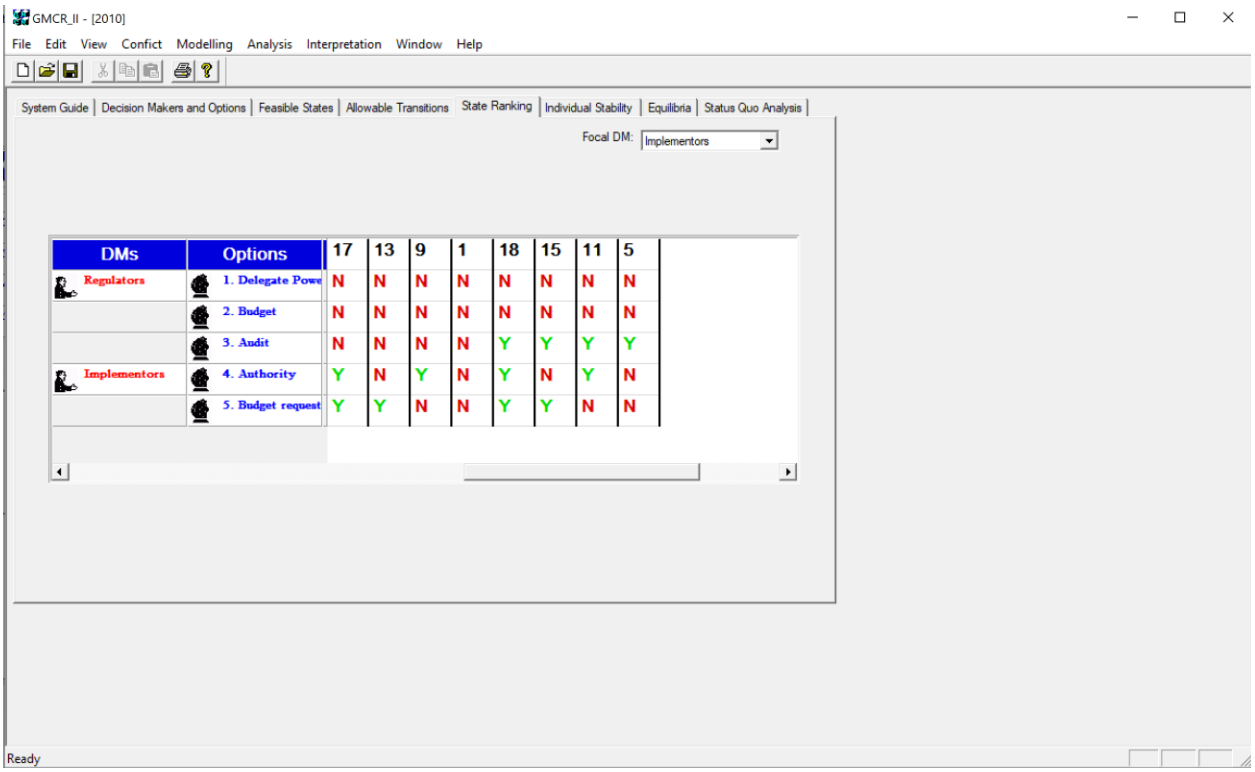


DMs	Options	13	9	17	3	10	6	16	8	2	14	4
Regulators	1. Delegate Powe	N	N	N	N	N	Y	Y	Y	Y	Y	Y
	2. Budget	N	N	N	Y	Y	N	N	Y	N	N	Y
	3. Audit	N	N	N	N	N	Y	Y	Y	N	N	N
Implementors	4. Authority	N	Y	Y	N	Y	N	N	N	N	N	N
	5. Budget request	Y	N	Y	N	N	N	Y	N	N	Y	N

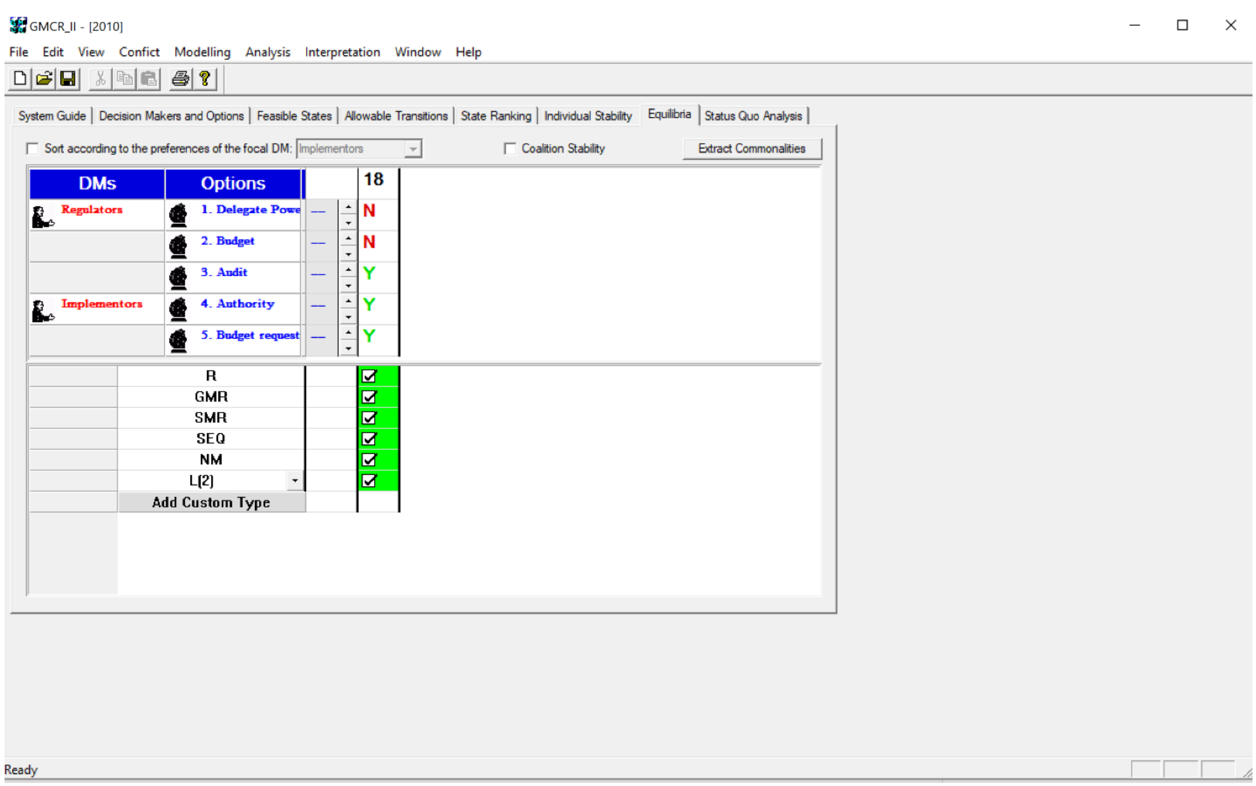
Appendix E.5. State Ranking (Preferences) for Implementers



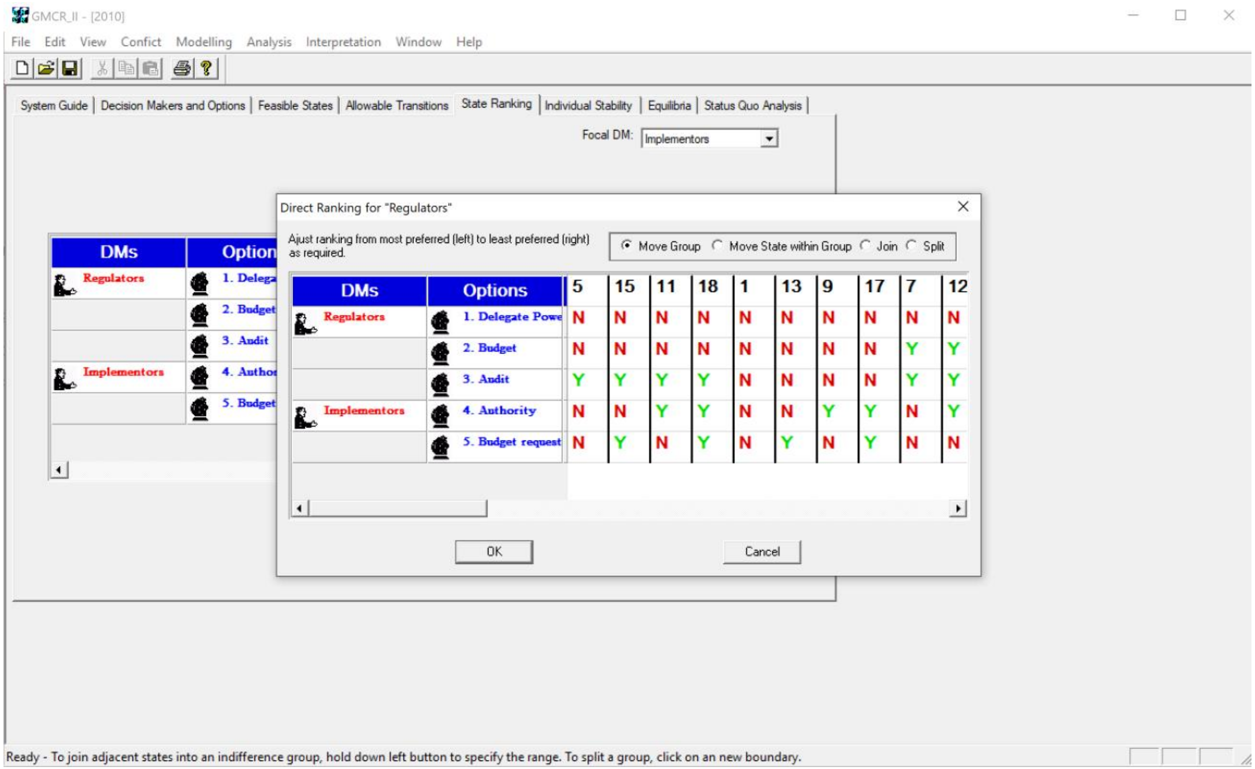
DMs	Options	4	8	10	3	12	7	14	2	16	6	17	1
Regulators	1. Delegate Powe	Y	Y	N	N	N	N	Y	Y	Y	Y	N	N
	2. Budget	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
	3. Audit	N	Y	N	N	Y	Y	N	N	Y	Y	N	N
Implementors	4. Authority	N	N	Y	N	Y	N	N	N	N	N	Y	N
	5. Budget request	N	N	N	N	N	N	Y	N	Y	N	Y	Y

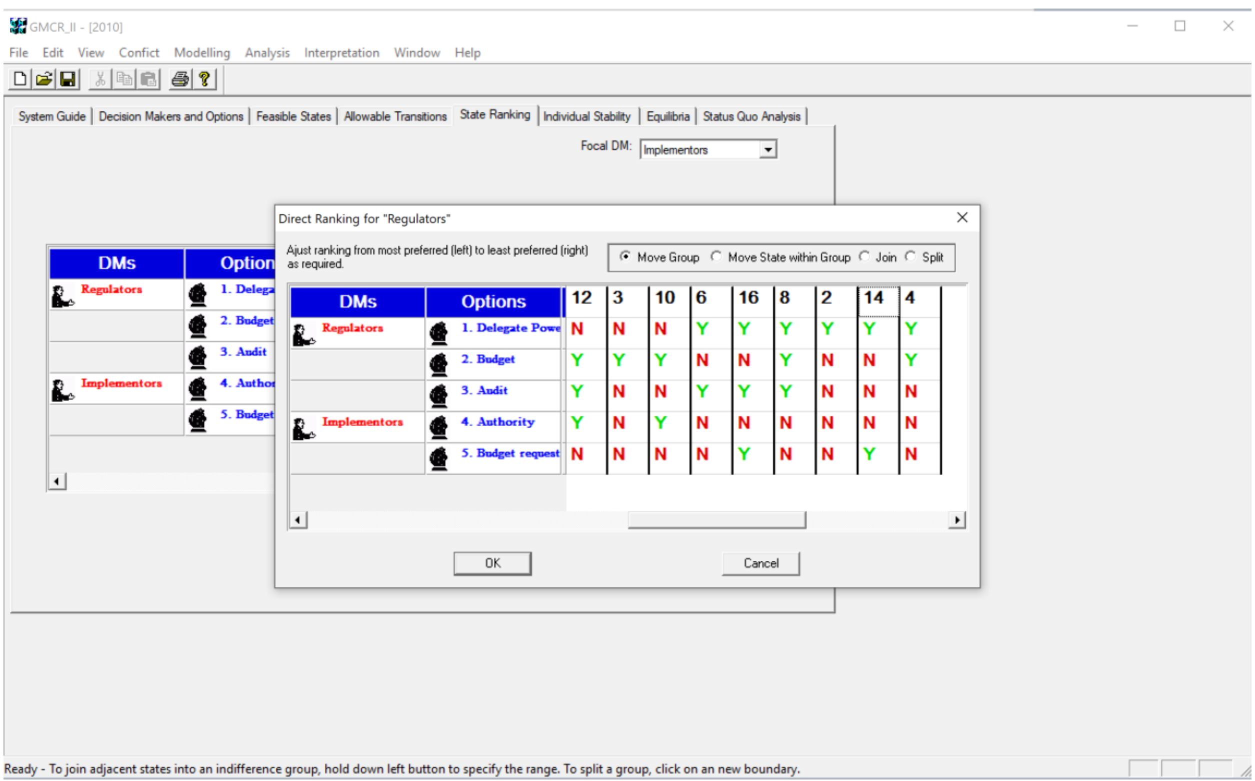


Appendix E.6. Equilibria (Stable State(s))

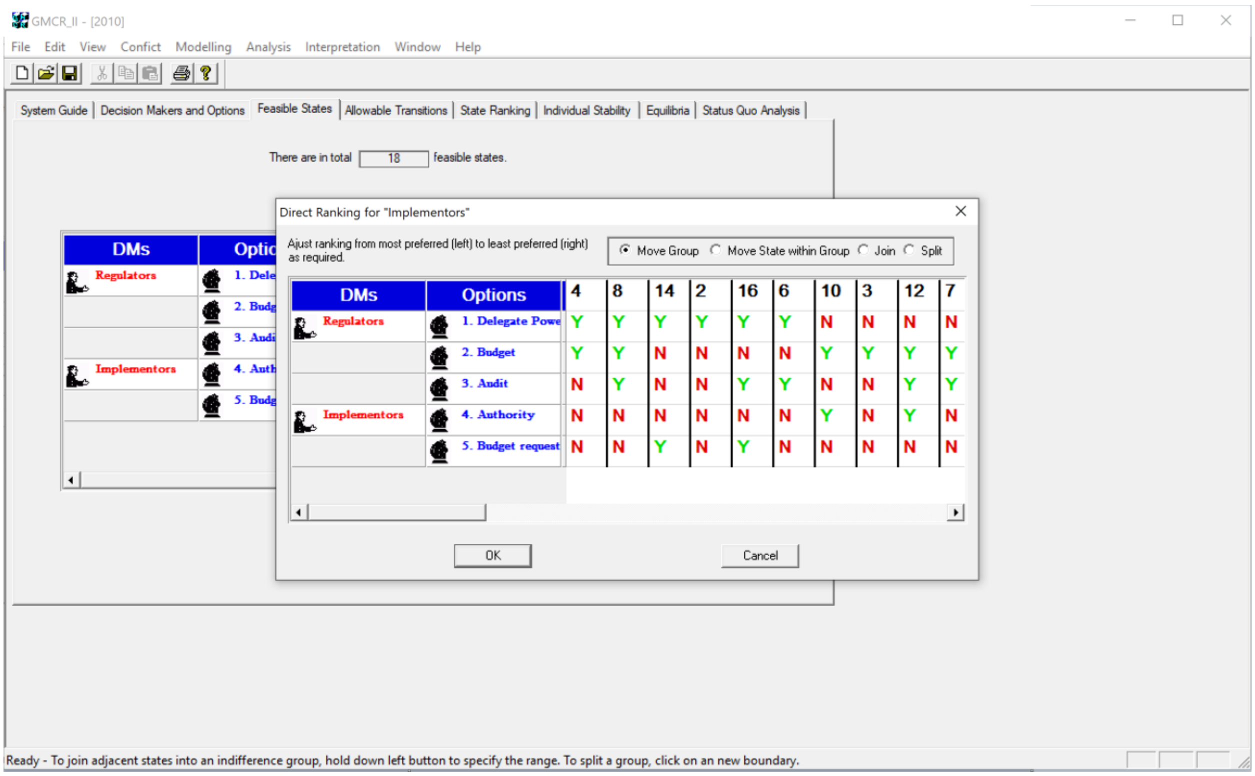


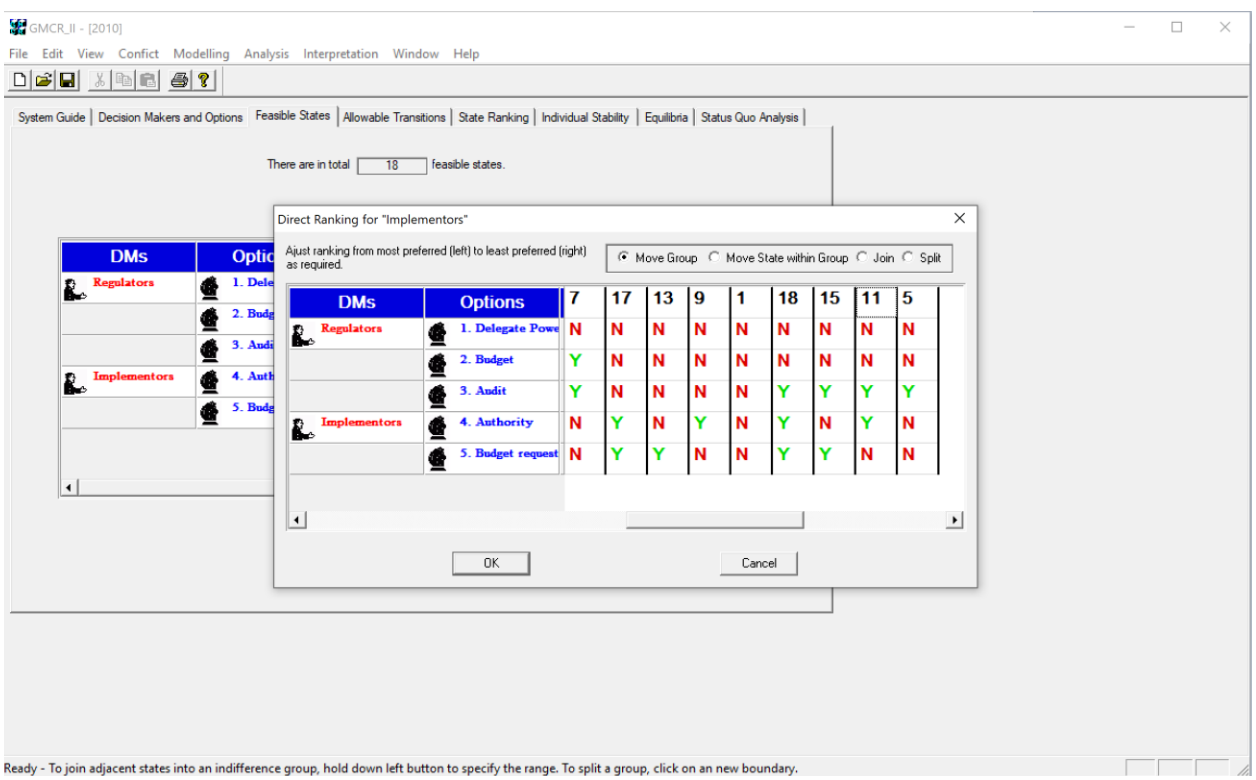
Appendix E.7. State Ranking (Preferences) for Regulators (Sensitivity Analysis)





Appendix E.8. State Ranking (Preferences) for Implementers (Sensitivity Analysis)





Appendix E.9. Equilibria (Stable State(s)) (Sensitivity Analysis)