VULNERABILITY OF A RUN-OF RIVER IRRIGATION SCHEME TO EXTREME HYDROLOGICAL CONDITIONS – A CASE STUDY OF THE BWANJE VALLEY IRRIGATION SCHEME, MALAWI

by

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A Thesis presented to The University of Guelph

In partial fulfilment of requirements for the degree of Master of Science (Planning) in Rural Planning and Development

Guelph, Ontario, Canada

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ABSTRACT

VULNERABILITY OF THE COMMONS TO EXTREME HYDROLOGICAL CONDITIONS
– A CASE STUDY OF THE BWANJE VALLEY IRRIGATION SCHEME, MALAWI

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University of Guelph                                                                 Professor John FitzGibbon

Irrigation plays an extremely important role in agriculture but climate change is predicted to modify climate patterns with potentially devastating consequences for irrigation. Potential impacts and adaptations are known, but not how implementation strategies may be implemented at the individual irrigation scheme level.

Using a case study approach and qualitative research methods this thesis describes the Bwanje Valley Irrigation Scheme (BVIS), Malawi in order to explain how water is managed. Subsequently, historical adaptations are described in order to draw conclusions concerning the vulnerability of the BVIS under normal and extreme hydrological conditions.

The BVIS is vulnerable in all conditions because it utilizes a common pool resource. As water supply decreases, irrigation water management becomes less and less equitable which makes the system extremely sensitive to changes in water supply. Capacity to adapt to climate change is limited to funding provided by external agencies which currently limit adaptations to reactive changes.
ACKNOWLEDGEMENTS

This research process has been the most challenging but most rewarding experience of my life. I have put so much of myself into this work, but numerous other people have assisted me along my journey. They each deserve special mention below.

First, I cannot thank Dr. John FitzGibbon enough for the support and encouragement that he has provided me throughout this process. You have always gone over and above in your willingness to assist me and for that I am forever grateful.

Second, I could not have completed this project without the assistance of Dr. Henrie Njoloma in Malawi. You were and always will be an inspiration for me in terms of the goals you set for improving water management in Malawi and beyond. Malawi is lucky to have you continually striving to improve conditions for the better.

Third, I extend the warmest appreciations to my research assistant Frank Vellemu. My research couldn’t have been completed without your help. I hope there is an opportunity for us to work together in the future as this thesis is in so many ways yours as well as mine. We figured out irrigation together and enjoyed ourselves at the same time.

Fourth, I cannot thank my mother enough for the continuous support you have provided me over the past two years. This thesis is because of you and for that I am truly thankful and forever grateful.

Finally, this thesis is dedicated to my daughter Autumn. You mean the world to me and continually inspire me to do better for our little family. I only hope that someday I can help you achieve your dreams in the same way the people acknowledged here have helped me. I look forward to teaching you all about wawa someday soon too.
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1 Introduction

1.1 Research Background

This introductory chapter introduces the thesis completed on the ‘Vulnerability of a Run-of-River Irrigation Scheme to Extreme Hydrological Conditions – A Case Study of the Bwanje Valley Irrigation Scheme (BVIS)’. Irrigation has played an extremely important role in benefiting agriculture throughout human history and specifically in underpinning the green revolution for the past 50 years (Postel, 1989). Indeed, irrigation has contributed between 50 and 60 percent of the massive increase in agricultural output in developing countries from 1960 to 1980 (Ostrom, 1992). Currently, 18 percent of all cropland is irrigated and those crops account for roughly 40 percent of the world’s human food supply (Gleick, 2000). The importance of irrigation cannot be overemphasized because for all intents and purposes it has allowed humanity to control water for its food production (Kay, 2001). These striking benefits have led to massive investments in irrigation technology with the “World Bank alone providing over $11 billion in loans for irrigation and drainage projects between 1947 and 1985, another $7.5 billion for area development projects that frequently included substantial irrigation activities” (Ostrom, 1992, p.2). Our dependence upon and investment in irrigation alone should necessitate the important question of what is the vulnerability of an individual irrigation system to the effects of climate change?

1.2 Problem Statement

Irrigation is itself a technological adaptation of traditional agriculture practices to normal climatic variability. Erratic rainfall, rainy seasons starting or finishing later, amongst others problems are all reasons for irrigated agriculture. The existence of
centuries old irrigation schemes such as the Balinese Subaks in Indonesia highlight that numerous systems have been capable of withstanding normal climatic variability (Ostrom, 1992), but climate change is predicted to further modify climatic patterns with potentially devastating consequences. Although local level predictions aren’t available, current climate change research has documented potential impacts as well as provided adaptation options on a regional and sectoral level. However, these strategies are conceived “without explicitly considering what adaptations options would be feasible” (Parry et al., 2007, p.198). What this means is that the problem is understood (i.e. what will happen or the impacts) but not how adaptation processes to resolve these problems would work at the local level. More research on process is needed because adaptation is not only a process, but an on-going process with a potentially constantly changing target. Therefore, in order to begin to answer how to adapt, an assessment of current vulnerabilities to extreme hydrological conditions (one potential impact of climate change) is a step forward towards better implemented adaptations.

1.3 Research Objectives

Production statistics highlight the importance of irrigation systems from a food security standpoint while the limits of current research reveal an implementation gap for adaptation to climate change at the level of an individual irrigation scheme. Therefore, this research seeks to better understand the institutional vulnerabilities of an individual irrigation scheme in order to assist policy makers with the implementation of climate change adaptation strategies. This broad research purpose informs the following objectives that were completed as part of this thesis:
1. To describe the physical and social systems of the Bwanje Valley Irrigation Scheme (BVIS) in terms of its structure, process, and function.

2. To explain how water is managed at the BVIS in terms of normal operating conditions and under extreme hydrological conditions (floods and droughts).

3. To describe system adaptations in response to internal and external stressors under normal operating conditions and possible extreme hydrological conditions.

4. To describe system vulnerabilities under normal operating conditions and extreme hydrological conditions.

1.4 Research Significance

From an examination of the literature there doesn’t appear to have been assessments completed of individual irrigation schemes in relation to their vulnerability to climate change. Therefore, this investigation will serve as a new area of climate change adaptation research. Additionally, “the implication for policy is profound and requires a shift in mental models toward human-in-the environment perspectives, acceptance of the limitation of policies based on steady-state thinking and design of incentives that stimulate the emergence of adaptive governance for social–ecological resilience of landscapes and seascapes. Not only adaptations to current conditions and in the short term, but how to achieve transformations toward more sustainable development pathways is one of the great challenges for humanity in the decades to come” (Folke, 2006, p.263). This thesis seeks to inform policy-makers about vulnerabilities so that future adaptation programs and projects may account for these deficiencies in their quest for sustainability. As Benjamin Franklin was quoted, “an ounce of prevention is worth a pound of cure.”
1.5 Research Limitations

First, this research is limited by the amount of time spent in the field which was approximately three months. Second, all fieldwork at the BVIS was completed between 8 AM and 6 PM as it was determined to be unsafe outside of these hours. Third, all fieldwork was completed during the dry season only, which limited direct observations. Therefore, all descriptions of events in the rainy season are limited to secondary sources and descriptions of farmers. Fourth, this research predominantly focussed on irrigation water management in order to understand system vulnerability. From an examination of irrigation water management, inferences are made about system performance, but examining system performance through one aspect limits generalizability to all aspects of the system although conclusions are drawn. Fifth, individual user characteristics were not a focus of this research study. Sixth, a predominantly farmer perspective was used during the completion of this research, which limited the incorporation of upper managements views into the research. Finally, all interviews and focus groups were conducted through a translator, which creates translation issues.
1.6 Thesis Structure

This thesis is made up of the following seven chapters:

- Chapter 1 – Presents the research problem, purpose, objectives, and relevance.
- Chapter 2 – Presents a review of the literature and a conceptual framework for the research.
- Chapter 3 – Explains the methodology followed during the design and implementation of the research.
- Chapter 4 – Presents rationale for case study selection and the background information on the case study selected for this research.
- Chapter 5 – Presents results gathered during the fieldwork completed for this research.
- Chapter 6 – Discusses the vulnerability of an irrigation scheme to extreme hydrological conditions.
- Chapter 7 – Presents conclusions for the research and recommendations from the research.
2 Lit Review

This chapter presents a review of the literature and both a conceptual framework and analytical framework for the research. Literature on systems, social-ecological systems, and irrigation systems are reviewed in order to describe the Bwanje Valley Irrigation Scheme (BVIS). In order to explain how water is managed at the BVIS, important aspects of governance, management, and institutions are discussed in order to present a conceptual framework for the research. Subsequently, literature on extreme hydrological conditions and adaptations is reviewed in order to describe system adaptations under normal operation conditions and extreme hydrological conditions. From this discussion, an analytical framework for vulnerability is presented in order to describe vulnerabilities of the irrigation scheme under normal operating conditions and extreme hydrological conditions.

2.1 Systems Framework

“...if a factory is torn down but the rationality which produced it is left standing, then that rationality will simply produce another factory. If a revolution destroys a government, but the systematic patterns of thought that produced that government are left intact, then those patterns will repeat themselves in the succeeding government. There’s so much talk about the system. And so little understanding” (Pirsig, 2008, p.88).

This study is an investigation about irrigation systems, and in order to understand irrigation it is first necessary to understand systems. The Pirsig (2008) quotation is used to introduce the concept of systems. It highlights the notion that how a system behaves is characteristic of all the components that make it up. And, this response or behaviour
is independent of whether the system is buffeted, constricted, triggered or perturbed by internal or external forces (Meadows, 2008). The following sections will further conceptualize how to think about systems.

2.1.1 System Models

A system is defined as “a set of things – people, cells, molecules, or whatever – interconnected in such a way that they produce their own behaviour over time” (Meadows, 2008, p.2). This behaviour was briefly described above, and the first step towards understanding is to model the system under investigation. The components of a basic system model include: boundaries, inputs, outputs, and an external environment. The system boundary is an imaginary line, which separates the component of study from the components that aren’t being studied. Across this boundary, systems receive inputs from their environment, which are then transformed through system processes into outputs that may be released back to the environment (Daellenbach and McNickle, 2005). Waste is considered an output along with the beneficial goods and services produced that cross or do not cross the system boundary. Inputs and outputs that cross a system boundary define its interaction with its surrounding environment. These interactions define whether a system is open, closed, or isolated with respect to its surrounding environment. Open systems exchange both mass and energy with their surrounding environment. Closed systems only exchange energy with their surrounding environment. Finally, isolated systems exchange neither mass nor energy with their environment (Chorley and Kennedy, 1971). How the components of a basic system model fit together are presented in Figure 1 - Basic System Model. Now that systems
have been modeled and situated within their external environment, their internal structure, process and function needs to be explained.

Figure 1 - Basic System Model

2.1.2 System Components

2.1.2.1 Structure

How the elements of a system fit together is its structure. This structure may be simple or complex depending on the nature of the relationships amongst elements. Simple structures may have hierarchical relationships for example; whereas complex structures would have more intricate relationships. Structures are made up of elements that humans can count, feel, see, and measure (Meadows, 2008). These elements may be tangible (i.e. machines, crops, animals) or intangible (i.e. capacity or vulnerability). Stocks represent the measure of an element at a specific time, but these stocks change over time through the action of flows. Flows increase, decrease, or maintain physical
and social (i.e. information) stocks. Elements move and change through system processes that are explained next.

2.1.2.2 Process

System processes are sequences of actions/events that utilize the internal and potentially external elements of a system in order to achieve something. Similar to structure, processes may be simple or complex depending on the sequence of actions. These processes may be carried out by people, nature, machines or a combination of these elements. Processes transform inputs into outputs, move resources across system boundaries, and modify or feedback on the system itself. Transformation processes convert inputs into outputs through a sequence of steps/tasks. Boundary processes move mass and energy, or only energy across the system boundary. The final type of system processes are feedback processes. Feedback occurs in a system when a consistent behaviour is observed over time. Two kinds of feedback exist and these are reinforcing and balancing. Reinforcing feedback generates exponential growth or collapse in a system, while balancing feedback generates forces of resistance that limit reinforcing behaviour. Balancing feedback may also be characterized as goal-seeking behaviour moving a system away from exponential growth towards an objective (Senge, 2006). For example, the water-level in a reservoir used to irrigate crops keeps getting lower and lower, and feedback explains why this outcome occurs. If a non-exhaustive supply of water existed then withdrawals from the reservoir could continue indefinitely. However, water is exhaustive and continuous withdrawals reduce available water causing a shortage. The outcome of this scenario is that the system continuously decreases no matter what is going on around it and this occurs because of a reinforcing
feedback loop. These processes are the bridge between the elements or structure of a system and a system’s ultimate goals and objectives (Senge, 2006).

2.1.2.3 Function/Purpose

The function or purpose of a system is the set of goals and objectives it strives to achieve. By convention, function is used to describe the objective of a physical system, whereas purpose is used to describe the objective of a social system (Meadows, 2008). These goals are accomplished through processes that utilize elements. While ecological systems achieve natural objectives, planned systems created by human are designed to achieve potentially both natural and social goals although they may not accomplish them. A system may be designed to distribute water efficiently, but if this system distributes water inefficiently then its actual function or purpose is to distribute water inefficiently. Function or purpose can be determined by watching the behaviour of a system over time and the outcomes it produces. Intended or unintended ultimate outcomes are the function/purpose of a system.

2.2 Social-Ecological Systems (SESs) Framework

As described above there are tangible (physical) and intangible (social) elements (stocks and flows), sequences of actions (processes, interactions), and outcomes (functions or purposes) that make up a system. Now that systems have been presented generally, it is important to begin to conceptualize irrigation systems specifically. This research focuses on irrigation systems which are an example of a resource system, and one of the most common terms used to describe these systems is social-ecological systems. Social-ecological systems are made up of an ecological component that refers
to the resource (renewable) being used and its surrounding environment and a social component that represents the individuals and/or organizations that use the resource. The term is hyphenated to represent that each of these component elements or sub-systems jointly influence outcomes (Berkes et al., 2002). A framework that incorporates the ecological as well as social elements of these systems is used to describe irrigation systems.

A multilevel, nested conceptual framework for social-ecological systems is used to situate all the components of an irrigation system within their surrounding environment (Ostrom, 2009). The first level of the multi-level framework relates resource systems (physical structures), resource units (i.e. crops produced, fish caught), governance systems (social structures) and users (i.e. farmers, fishermen) (Poteete et al., 2010). Additionally, the four previously mentioned subsystems are situated within a social, economic, and political setting, and related ecosystem to highlight influences beyond system boundaries. This framework then allows for the interactions (processes) and outcomes (function/purpose) of these complex SESs to be studied. **Figure 2 - First Level Variables** (Ostrom, 2007b, p.15182) displays graphically the relationships between the eight components of the first-level of the SES framework. Although important, the users of the resource system were not a focus of this thesis, and therefore this variable is omitted from further discussion and analysis. In its place, background information on irrigation in Malawi is presented in order to inform the evolution of irrigation in the Bwanje Valley to be discussed in the case study chapter. Each of the remaining first level variables is discussed individually in the remainder of this literature review.
In addition to the first level variables described above, there are second level variables and deeper level variables. “[The] choice of relevant second or deeper levels of variables for analysis (from the large set of variables at multiple levels) depends on the particular questions under study, the type of SES, and the spatial and temporal scales of analysis” (Ostrom, 2009, p.420). Many second level variables are beyond the scope of this thesis, and therefore only those second level variables that are relevant to the thesis are utilized moving forward. Where necessary, all variables requiring clarification will be discussed in this chapter. The second level variables used in this study are presented below in Table 1 - Second Level Variables (Ostrom et al., 2009, p.421).
<table>
<thead>
<tr>
<th>Related Ecosystems (ECO)</th>
<th>Resource Units (RU)</th>
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<tbody>
<tr>
<td>ECO1 Geology and Geography</td>
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<td>ECO2 Temperature</td>
<td>RU2 Water Delivery</td>
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<td>ECO3 Rainfall</td>
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<td>ECO4 River Discharge</td>
<td>GS1 Resource Type</td>
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<td>ECO5 Climate Change</td>
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<td>IM2 Irrigation Development</td>
<td>O1 Production</td>
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<td>IM3 Legal Framework</td>
<td>O2 Adaptation</td>
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<tr>
<td>IM4 Evolution of Irrigation in the Bwanje Valley</td>
<td>O3 Vulnerability</td>
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Table 1 - Second Level Variables (Ostrom et al., 2009, p.421)

### 2.3 Irrigation Systems

Now that systems have been conceptualized and placed within a social-ecological systems (SES) framework, irrigation systems will be described. In layman's terms,
irrigation is the replacement or supplement of rainwater with another source of water for agriculture. More technically, irrigation is defined as the “human intervention to modify the spatial or temporal distribution of water occurring in natural channels, depressions, drainage ways or aquifers and to manipulate all or part of this water for the production of agricultural crops” (Small and Svendsen, 1990, p.285). There are numerous forms of irrigation including: sprinkler, drip, sub-irrigation and surface. Sprinkler irrigation distributes water via system of overhead water guns whereas drip irrigation delivers water directly to the root zone of a crop via a piped network. Sub-irrigation artificially raises the water table allowing the root zone of crops to be moistened from below. Finally, surface irrigation and its variety of forms (i.e. canal, furrow, borderstrip, and basin) all apply and distribute water over the soil surface by gravity. All these forms of irrigation deliver water to crops via a network of pipes or canals. Pipes can be either aboveground in sprinkler irrigation or belowground in localized/drip irrigation, whereas canal irrigation delivers water aboveground through a system of channels (Laycock, 2007). Canal irrigation is the focus of this thesis and its numerous physical and institutional components within irrigation schemes are explained below.

2.3.1 Resource System

The physical irrigation system comprises the following major processes: acquisition (abstraction); distribution; and drainage. These processes are the same transformation processes described above with abstraction taking water from the environment and inputting it into the distribution process. The distribution process then transports water throughout the entire irrigation scheme to be used by farmers. Excess
water is directed to the drainage system which outputs it back to the surrounding environment. These major processes are further described below.

2.3.1.1 Abstraction

The acquisition/abstraction structures are the first step in an irrigation system as these structures make water available for agriculture within the scheme. Abstraction is accomplished by directly diverting water from a river, taking water that’s been impounded behind a dam, withdrawing water from a lake, or pumping of groundwater to the surface. When water is abstracted from a river, irrigation schemes may be conventional (i.e. dammed) or run-of-river referring to whether water is abstracted from a reservoir or from water coming from upstream at any given moment. Once water is abstracted, treatment of the input water may need to be performed in order to remove excess sediment from the water. Settling basins are normally used to trap sediment, which is then settled out of the water stream and outputted back to the environment (Laycock, 2007). Once sediment is removed, water is conveyed to the distribution/conveyance structures.

2.3.1.2 Distribution

The most obvious physical component of a canal irrigation scheme is its set of canals. Canals distribute water throughout the irrigation system from where it is abstracted. This distribution system serves the functional purpose of delivering water directly to the farmer’s fields where it is used to produce agricultural crops. The canals that carry the water come in a variety of shapes including: trapezoidal, parabolic, triangular, rectangular, and circular with shape ultimately dependent on design
considerations. Trapezoidal canals are the common engineering standard. The second design consideration for canals is whether they should be lined or unlined. The most practical reason for lining canals is to reduce water losses (seepage) in the canals, otherwise vast quantities of water are not made available for crops. Additionally, lining canals protects against damage from animals, makes maintenance easier, and increases delivery efficiencies. Cost is a major factor in not lining canals. The canals are the distribution or conveyance structures within an irrigation scheme (Laycock, 2007).

It is common to distinguish canals as primary, secondary, and tertiary. Primary canals represent the main system canals which transport water from any pre-treatment operations to the secondary canals. Secondary canals distribute water to different sub-areas of an irrigation scheme. Finally tertiary canals deliver water directly to the fields for application to the crops. There are field level canals but these earthen channels are constructed based on farmer preference for how they wish to direct water within their fields. Control within the distribution system of an irrigation scheme is possible via a system of gates which can be manual, motorized or both depending on system design.

Scheduling within an irrigation scheme may be accomplished in one of the following ways: uncontrolled continuous flow; supply scheduling; demand scheduling; and flexible arranged scheduling. Uncontrolled continuous flow as the term implies is where water flows continuously through the canal system with no intermediate control or regulation. In a supply scheduled system water is controlled from the top down with some management organization responsible for all aspects of abstraction and distribution. In a demand scheduled system water is controlled from the bottom up with farmers taking water as and when they need it. Flexible Supply scheduling is a bottom-up oriented system with management undertaken by a cooperative or water-users
associations (Laycock, 2007). For all the scheduling approaches described above, they are designed based on crop water requirements.

The term crop water requirement is defined as the amount of water that needs to be supplied to a crop in order for it to grow. Based on a given crop’s water requirements, a water schedule is developed that provides water at a specific time (frequency) throughout the growing season for a defined period of time (duration). In most supply scheduled systems, a water rotation is used where water is allowed to flow into a canal for a predetermined set of time, and the canal is subsequently closed until its turn comes around again. Rotations of 1-2 weeks are common, but may be more or less depending on water availability and crop water requirements. Indenting is a more flexible supply schedule system where a farmer requests water each time it is needed, but system management is responsible for controlling the specific release of water. In demand scheduled systems, water can be taken either as needed or in an arranged schedule, roughly similar to indenting. Arranged scheduling is possible in systems with more water than farmers because not all farmers need water at the same time allowing it to almost function as a pure demand scheduled system.

2.3.1.3 Drainage

All excess water must be drained from an irrigation system in order to prevent ponding and/or waterlogging. Ponding is the accumulation of excess water on the soil surface from over irrigation or excessive rainfall whereas waterlogging is the accumulation of excess water in the root zone of the soil (FAO, 1996). Surface drainage prevents ponding and subsurface drainage prevents waterlogging. “Drainage can be either natural or artificial. Most areas have some natural drainage; this means that
excess water flows from the farmers’ fields to swamps or to lakes and rivers. Sometimes, however, the natural drainage is inadequate to remove the extra water brought in by irrigation. In such a case, an artificial or man-made drainage system is required. A man-made drainage system is an artificial system of surface drains and/or subsurface drains, related structures, and pumps (if any) to remove excess water from an area” (FAO, 1996, p.7). Artificial surface drainage is accomplished through grading the land so that all water is conveyed towards open drains (channels) that direct water out of the field. Artificial subsurface drainage can use either open drains or may require perforated subsurface pipes that capture subsurface water and direct it out of the field through gravity.

2.3.2 Governance System

The governance system of an irrigation scheme comprises the organizations, processes, actors, and regulations that are humanly designed in order to govern, manage, operate and maintain the physical and social structures of any system. The following section describes in detail these components.

2.3.2.1 Organizations

An organization is defined as “a social entity that is goal directed and deliberately structured. Social entity means being made up of two or more people. Goal directed means designed to achieve some outcome. Deliberately structured means that tasks are divided and responsibility for their performance is assigned to organizational members. This definition applies to all organizations, including both profit and not-for-profit” (Daft, 2003, p.9).
For irrigation, there are numerous types of organizational designs. These types are integrated management organizations, specialized water management organizations, and multi-purpose water management organizations. First, integrated management organizations such as state farms, cooperatives, or community managed systems manage all the affairs (i.e. water management, agricultural extension, applied research, supply of inputs and credit, marketing, and social services) of an irrigation scheme. State farms are government managed whereas cooperatives are private organizations. Cooperatives are formal organizations created by a group of farmers to manage and farm the land. Community-based organizations manage systems based on customary traditions or other self-organized initiatives. Cooperatives and associations in irrigation management are a more recent phenomenon due to government decentralization. The transfer of management from public schemes to cooperatives or associations is known as irrigation management transfer, which has been common in irrigation for the past 30 years. Second, associations are an example of a specialized water management organization that focuses solely on operation and maintenance of irrigation structures for a fee as compared to cooperatives which manage all the affairs of an irrigation scheme. Finally, multi-purpose water management organizations exist to manage water used for more than irrigation, but these organizations are beyond the scope of this thesis. All the different types of organizations discussed may have mixed control (i.e. main irrigation system managed by government while tertiary canals are managed by farmers) (Sagardoy et al., 1986).
2.3.2.2 Governance Regimes

Individual organizations have a structure (configuration and goals), but these organizations may or may not be embedded in a governance regime that spans multiple organizations. Governance is defined as “the exercise of authority through formal and informal traditions and institutions for the common good. Governance includes: (i) the process by which those in authority are selected, monitored and replaced; (ii) the capacity to effectively manage resources and implement sound policies; (iii) the respect of citizens for the institutions that govern economic and social interactions among them" (Thomas et al., 2000, p.137).

Governance regimes can be characterized as public, private, communal, or open access. Public regimes are run by government, private regimes are controlled by citizens for profit, communal regimes are controlled through complex community norms, and open access implies no regime being present. There are two basic governance regimes depending on whether mixed control is present or not. “The first is the centralized (unicentric) model, in which a single unified public organization is empowered to make decisions regarding management of the irrigation scheme. This centralized organization is not necessarily ‘authoritarian’, but does centralize authority under a governance process that may be more or less democratic. The second is the decentralized (polycentric, coordinative) model, in which layers of government and other organizations are coordinated to cover an entire irrigation scheme” (Svendsen et al. (2005, p.15).

Centralized governance (i.e. government) is possible in some contexts, but polycentric governance is becoming more common due to government decentralization and irrigation management transfer. Polycentric governance involves multi-level
hierarchies with the nesting of rights, rules and roles at different levels - similarly to the nesting of computer languages. “What can be done at a higher level will depend on the capabilities and limits of the rules (or the software) at that level and at a deeper level” (Ostrom, 2007a, p.44). Kiser and Ostrom (1982) distinguish three levels that cumulatively affect the actions and outcomes in a polycentric governance regime. These three levels are operational, collective-choice, and constitutional. The operational level is where the day-to-day decisions of farmers are made regarding operation and maintenance. The collective-choice level is where decisions are made regarding management of an irrigation scheme, which directly affect how farmers make their decisions regarding operation and maintenance. Finally, the constitutional is where decisions are made regarding governance, which directly affects the collective-choice level in terms of how the organization is formed, how members are elected, and broad policy initiatives. All levels contain various roles, rights, and rules and these are discussed in the next section. The multiple levels discussed above are displayed in **Figure 3 - Multiple Levels of Governance.**
2.3.2.3 Institutional Mechanisms

Roles

Institutions are formally defined as “humanly devised constraints that shape human interaction and consist of different mechanisms that persist over time and inform action” (Svendsen et al., 2005, p.4). Three different types of institutional mechanisms are roles, rights, and rules. In order to understand roles, actors need to be defined first. Actors are individuals or organizations who take actions in the governance, management, and operation of a system. Roles are sets of expectations and tasks
assigned to a particular actor (Svendsen, 2005). In the context of an irrigation scheme, roles can be farmer, maintenance worker, cooperative president, or scheme manager depending on how functions/activities are divided for a given organizational structure. Specific roles will be more defined in the results chapter. The responsibilities and constraints placed on roles are discussed in the next section.

Rights

Rights refer to particular actions that are authorized (Schlager and Ostrom, 1992, p.250). More generally they may be thought of as responsibilities or entitlements that roles are assigned or granted. Rights may be formal or informal with formal rights given lawful recognition by government whereas informal rights are customary. Schlager and Ostrom (1992) further define rights according to the level at which they operate, which coincide with the multiple levels in governance regimes. Operational rights are access and withdrawal rights, which define the right of an individual to enter a defined common pool resource system and the right to obtain products of that resource system respectively. Constitutional and collective choice rights are not just entitlements but responsibilities in regulating how resources are used and how access rights are defined. Whether a right is constitutional or collective-choice depends on the type of governance regime and how it is organized. Constitutional rights grant roles the responsibility to create rules and rights at the collective choice level whereas collective-choice rights grant roles the responsibility to create rules and rights at the operational level. Rights are both privileges and responsibilities that are authorized by rules, which are discussed next.
Rules

Schlager and Ostrom (1992, p.250) define rules as “generally agreed-upon and enforced prescriptions that require, forbid, or permit specific actions.” Rules aim to achieve particular actions or outcomes in a system. Depending on the level of a rule, it may affect all, some or one situation(s) in a system. The level of a rule is again a reference to the multiple levels of a governance regime. Rules influence the behaviour of actors by permitting, obliging or forbidding their actions. When rules limit all actions they are constitutional-level policies whereas when rules limit one action in a specific context they are operational-level policies. Broad rules are harder to enforce as they aren’t necessarily bound to a particular time and place. When rules prescribe actions for a particular event, sanctions may be brought against those individuals that do not follow the rule. Rules limit the actions of actors in order to achieve specific outcomes (Ostrom, 2005).

2.3.3 Resource Units

2.3.3.1 Resource Types

From the public policy literature, there are four major types of resources. These resources are private, public, communal, and open access. How to distinguish between the different resources is to understand that they all can be defined according to two characteristics which are excludability and subtractability (rivalry) (Ostrom and Ostrom, 1977). Excludability refers to the physical nature of the resource and how costly or impossible it is to control access by potential users. Migratory resources such as fish, wildlife, and groundwater are almost impossible to control whereas range and forest lands pose costly problems related to exclusion. Subtractability refers to how the level of
exploitation of one user has the ability to adversely affect the ability of another user to exploit a resource. For example, if one user harvests fish from a lake then that fish is no longer available to other fishermen (Ostrom, 1990). The relationship between resource types, and their associated subtractability and excludability is shown in Table 2 - **Types of Resources** (Ostrom et al., 1994, p.6).

<table>
<thead>
<tr>
<th>Resource Types</th>
<th>Subtractability (Rivalry)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Excludability</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 - Types of Resources (Ostrom et al., 1994, p.6)

2.3.3.2 Resource Units

The resource unit used in irrigation schemes is water, which is a common-pool resource. Units of this resource can be described using a set of 5 variables. These 5 variables can be used qualitatively or quantitatively to describe the amount of water supplied or demanded. These 5 variables are magnitude, frequency, duration, timing and rate of change. The formal definitions for these variables are presented in Table 3 - **Definitions of Flow Variables** (Poff et al., 1997, p.770). These variables allow for the description of the resource units used by farmers in the irrigation scheme, so that quantities of the resource used may be understood.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnitude</td>
<td>The magnitude of discharge at any given time interval is simply the amount of water moving past a fixed location per unit time. Magnitude can refer either to absolute or to relative discharge (e.g., the amount of water that inundates a floodplain). Maximum and minimum magnitudes of flow vary with climate and watershed size both within and among river systems.</td>
</tr>
<tr>
<td>Frequency</td>
<td>The frequency of occurrence refers to how often a flow above a given magnitude recurs over some specified time interval. Frequency of occurrence is inversely related to flow magnitude. For example, a 100-year flood is equalled or exceeded on average once every 100 years (i.e., a chance of 0.01 of occurring in any given year). The average (median) flow is determined from a data series of discharges defined over a scientific time interval, and it has a frequency of occurrence of 0.5 (a 50 percent probability).</td>
</tr>
<tr>
<td>Duration</td>
<td>The duration is the period of time associated with a specific flow condition. Duration can be defined relative to a particular flow event (e.g., a floodplain may be inundated for a specific number of days by a ten-year flood), or it can be a defined as a composite expressed over a specified time period (e.g., the number of days in a year when flow exceeds some value).</td>
</tr>
<tr>
<td>Timing</td>
<td>The timing, or predictability, of flows of defined magnitude refers to the regularity with which they occur. This regularity can be defined formally or informally and with reference to different time scales.</td>
</tr>
<tr>
<td>Rate of Change</td>
<td>The rate of change, or flashiness, refers to how quickly flow changes from one magnitude to another. At the extremes, &quot;flashy&quot; streams have rapid rates of change, whereas &quot;stable&quot; streams have slow rates.</td>
</tr>
</tbody>
</table>

Table 3 - Definitions of Flow Variables (Poff et al., 1997, p.770)
2.3.4 Related Ecosystems

2.3.4.1 Climate Change (Extreme Hydrological Conditions)

According to the United Nations Environment Programme (UNEP), climate change is now recognized as the major environmental problem facing the globe. Potential impacts from climate change on water resources, such as irrigation systems, may include an increase in extreme hydrological conditions, which may lead to system specific vulnerabilities (IPCC, 2007). However, these conditions have always affected social-ecological systems and “despite the fascinating achievements of science and technology in the 20th century, continue to hit every generation of human beings, bringing suffering, death, and immense, and still growing, material losses” (Kundzewicz and Kaczmarek, 2000, p.66). A simple typology describes these events as they increase in magnitude. “Meteorological droughts occur when an area experiences low precipitation over a given time period. Hydrological drought implies flows and low levels of surface water (rivers, lakes) and of groundwater. Agricultural drought refers to low soil moisture and its effects on cultivated vegetation. Socio-economic drought occurs when the demand for water and water-related economic goods and services (e.g. fish hydropower, irrigated agriculture and horticulture) exceed supply” (Kundzewicz et al., 2002, p.263). The term flood indicates “out-of-bank flow, when the normal channel cannot convey the total water flow, which spills beyond the channel causing damage” (Kundzewicz et al., 2002, p.264). The classification of a flood specifically relates to the river or lake topography where water levels are greater than the natural or man-made features intended hold the river or lake water.
2.3.5 Interactions

2.3.5.1 Water Management Processes

Water management is accomplished through several management processes. These processes are planning, organizing, leading and controlling. These four processes are the primary activities or functions of managers described in most modern management textbooks (Daft, 2005).

Planning Processes

The planning processes category encapsulates two primary activities which are planning and decision-making. Chambers (1988) classifies the goals and objectives of irrigation as relating to purpose or the effects and impacts that an irrigation scheme is intended to have. These impacts include employment and income, security against impoverishment, food security, migration (stopping previous out-migration, and attracting in-migration), and quality of life. Planning is the setting of these goals and objectives for an individual, or organization. Within an irrigation scheme these goals and objectives can be for the scheme as a whole during all phases of construction, operation and maintenance or associated with specific functions such as abstraction, distribution and drainage (Uphoff, 1986).

In addition to the setting of goals and objectives, planning processes include the activity of decision-making. Decision-making is the process of choosing the preferred alternative amongst a set of possible alternatives. March (1994) describes the decision-making as the process of listing all possible alternatives to a problem, predicting the consequences of all alternatives generated, the ranking of preferences associated with
predicted consequences, and the rules (i.e. maximizing or satisficing) used to ultimately make a decision. These two functions are the first activities completed in irrigation water management.

Organizing Processes

Organizing processes along with planning processes constitute the two management processes associated with organizational design. “Organizing processes are defined as the deployment of organizational resources to achieve strategic goals” (Daft, 2005, p.312) as defined by planning processes. More specifically, organizing processes can be understood as the structuring (configuration), and sequencing (scheduling) of resources within an organization in order to achieve outcomes in an organization's organizational design or framework. This framework is a static, idealized representation of how an organization intends to achieve its goals. Structuring processes are defined as how stock resources are organized within a system. This idea is similar to the organization of individuals within an organization as displayed in an organizational flowchart. Structuring can be for an organization as a whole or for a specific process or activity. Sequencing (scheduling) processes are defined as how flow resources are distributed within a system. These two processes structure the stocks and flows that make up and are used by a system.

Leading Processes

Leading is the process of coordination and communicating how a system should be operated and maintained after it has been designed or conceptualized. Where
planning and organizing processes are design phase activities, leading is a process that ensures design criteria are achieved after a system has been implemented. If design proposes a theoretical framework for a system then leading implements the theoretical framework and communicates and coordinates turning the design into reality as closely as possible. Communication processes are the activities whereby management describes the outcomes of planning and decision-making processes. Coordination processes are the activities whereby management describes schedules and sequences to subordinates.

Controlling Processes

Control processes are the monitoring, sanctioning and conflict resolution activities that dictate how management and farmers interact within an irrigation scheme. An irrigation schedule explains how water is to be managed, but controlling that schedule to ensure it is followed is another matter. Monitoring processes are the activities whereby management observes and records system processes to ensure they are being operated or maintained as planned. Sanctioning processes punish subordinates or management for not following the rules of the system. Conflict resolution processes solve disputes related to the governance, management, and operation of an irrigation scheme. Control processes are accomplished through institutional mechanisms as described above, which are part of the institutional make up of an irrigation scheme. Please refer to Table 4 - Management Activities for a summary of the management activities described above.
### Table 4 - Management Activities

<table>
<thead>
<tr>
<th>Process</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Setting of goals and objectives for an individual or organization</td>
</tr>
<tr>
<td>Decision-Making</td>
<td>Process of choosing the preferred alternative amongst a set of possible alternatives</td>
</tr>
<tr>
<td>Structuring</td>
<td>How stocks are arranged within a system.</td>
</tr>
<tr>
<td>Sequencing</td>
<td>How flows are distributed within a system.</td>
</tr>
<tr>
<td>Coordination</td>
<td>Description of structure and sequences to subordinates.</td>
</tr>
<tr>
<td>Communication</td>
<td>Description of the outcomes of planning and decision-making processes.</td>
</tr>
<tr>
<td>Monitoring</td>
<td>Observation and recording of system processes.</td>
</tr>
<tr>
<td>Sanctioning</td>
<td>Punishment of individuals for not following rules.</td>
</tr>
<tr>
<td>Conflict Resolution</td>
<td>Dispute resolution process.</td>
</tr>
</tbody>
</table>

2.3.5.2 Conceptual Framework for Water Management

Building from a conceptual framework for irrigation water management developed by Uphoff (1986) and combining it with the SES framework, a modified conceptual framework that explains irrigation water management is developed. Please refer to **Figure 4 - Irrigation Water Management Conceptual Framework** for a graphical representation of this conceptual framework. This framework combines the resource system, the governance system, and the resource unit subsystems of the SES framework in order to explain irrigation water management as an interaction of these components. Both the resource system and the governance system are made up of
several processes that achieve irrigation water management and these processes were described above.

Figure 4 - Irrigation Water Management Conceptual Framework

2.3.6 Outcomes

2.3.6.1 Adaptation

A modified version of the IPCC definition for climate change adaptation is that it is an adjustment in natural or human systems in response to internal or external stresses or their effects, which moderates harm or exploits beneficial opportunities (Parry et al., 2007). And, any irrigation system which has lasted more than one growing season has responded to stresses (i.e. changing water levels, increased temperatures, etc…) through an adaptation process. While adaptation may be thought of as both an outcome
and a process only the former will be part of this thesis. This thesis seeks to inform adaptation processes, but only examines adaptation outcomes in order to characterize system vulnerabilities. There are different types of adaptations depending on what part of the system they modify. Tactical adaptations refer “to a refinement of actions to improve performance without changing guiding assumptions and calling into question established routines” (Pahl-Wostl, 2009, p.359). Strategic adaptations refer “to a change in the frame of reference, and the calling into question of guiding assumptions...[It also] implies a reflection on goals and problem framing (priorities include new aspects, change boundaries of system analysis) and assumptions how goals can be achieved” (Pahl-Wostl, 2009, p.359). Transformative adaptation refers to a change “of the structural context and factors that determine the frame of reference” (Pahl-Wostl, 2009, p.359). Simply put, tactical adaptation refers to mechanisms to improve system efficiency, strategic adaptation refers to mechanisms to improve system effectiveness, and transformative adaptation refers to mechanisms to improve system impact. Impact may be thought of as wholesale system change or the changing of a system into an entirely different system in order to achieve a different outcome.

All adaptations are driven by four questions which are: what to adapt to; who or what adapts; how does adaptation occur; and what are the limits to adaptation. The first question refers to whether a stress is internal (endogenous) or external (exogenous) to a system. The second question refers to the level, system, and type of adaptation. Level refers to whether an adaptation is tactical, strategic or transformative. Type refers to whether an adaptation modifies all activities (policy), some activities (process), or one activity. System refers to whether an adaptation occurs within the governance or
resource systems of an SES. Adaptations for the resource system would be considered technological whereas those focussed on the governance system would be considered institutional. The third question describes the characteristics of the specific adaptation. These characteristics are intent and timing. While intent refers to whether an adaptation is spontaneous or planned with respect to implementation, the timing refers to whether an adaptation is proactive or reactive with respect to a given stress. Finally, the fourth question refers to the temporal and spatial scope of adaptations. Temporal scope may be long-term or short-term, and spatial scope may be localized (sub-system) or widespread (whole system) (Pelling, 2011). A typology of these adaptation characteristics is presented below in **Table 5 - Adaptation Characteristics**.
<table>
<thead>
<tr>
<th>Question</th>
<th>Characteristic</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>What to adapt to?</td>
<td>Stress</td>
<td>Endogenous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exogenous</td>
</tr>
<tr>
<td>Who or what adapts?</td>
<td>Level</td>
<td>Tactical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strategic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transformative</td>
</tr>
<tr>
<td></td>
<td>Type</td>
<td>Policy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity</td>
</tr>
<tr>
<td></td>
<td>System</td>
<td>Governance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resource</td>
</tr>
<tr>
<td>How does adaptation occur?</td>
<td>Intent</td>
<td>Spontaneous</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planned</td>
</tr>
<tr>
<td></td>
<td>Timing</td>
<td>Proactive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reactive</td>
</tr>
<tr>
<td>What are the limits to adaptation?</td>
<td>Temporal Scope</td>
<td>Short-term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long-term</td>
</tr>
<tr>
<td></td>
<td>Spatial Scope</td>
<td>Localized</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Widespread</td>
</tr>
</tbody>
</table>

Table 5 - Adaptation Characteristics

2.3.6.2 Vulnerability

Vulnerability is defined as “the degree to which a system, subsystem, or system component is likely to experience harm due to a stress” (Turner et al., 2003, p.8074). In
comparison to adaptation, vulnerability is a measure of the ability of a system to adapt while adaptation is the actual outcome. Several approaches to vulnerability analysis have evolved from a number of traditions and disciplines (Adger, 2006), but the risk-hazard (RH) and pressure-and-release (PAR) models have most informed the systems oriented approach to vulnerability developed by Turner et al. (2003). The RH model predicts the impact of a hazard as a function of exposure (stress) and sensitivity (impacts) of the entity exposed. This approach allowed for climate change impact assessments to be completed working from the stress to the impact. However, this approach neglected a system’s capacity to adapt and the role of economic, social and political institutions from the surrounding environment in shaping exposures, sensitivities and capacities to adapt. Essentially, the RH approach neglected that a system is situated within an external environment that may directly or indirectly affect the system’s ability to respond. Subsequently, the PAR model defined vulnerability as a function of the stress (exposure and sensitivity) and the adaptive capacity of an exposed unit. This approach goes beyond impacts to emphasize the conditions that make a unit unsafe in the first place. However, neither the RH nor the PAR models address the specific vulnerabilities of social-ecological systems (Turner et al., 2003).

Building from the above described models, the Turner et al. (2003, p.8076) framework “provides the broad class of components and linkages that comprise a social-ecological system’s vulnerability to hazards. The basic architecture consists of: (i) linkages to the broader human and biophysical (environmental) conditions and processes operating on the coupled system in question; (ii) perturbations and stressors that emerge from these conditions and processes; and (iii) the coupled human–
environment system of concern in which vulnerability resides, including exposure, sensitivities and responses (i.e. hazard, impacts and adaptations).” Exposure is a measure of the size and the temporal and spatial characteristics of a hazard. Similarly to the variables used to define the resource units of a social-ecological system, there are seven (7) measures of hazardous events which are: magnitude, frequency, areal extent, speed of onset (rate of change), duration, spatial dispersion and temporal spacing (timing) (Burton et al., 1993). While magnitude, frequency, duration, timing and rate of change have already been defined, areal extent refers to the space covered by a hazard and spatial dispersion refers to the movement of a hazard over time (i.e. a tornado moving across a landscape). “Sensitivity is the degree to which a system is affected, either adversely or beneficially by a hazard” (IPCC, 2007, p.881). These sensitivities or impacts may be direct or indirect depending on the specific exposure characteristics. These exposures and sensitivities are then related to system adaptations in order to assess whether a system is capable of positively responding to a hazard.

2.3.6.3 Analytical Framework for Vulnerability

Using the Turner et al. (2003) framework as a foundation, a conceptual framework for vulnerability analysis is presented below. Please refer to Figure 5 – Vulnerability Analytical Framework for a presentation of the elements within this framework. This framework shows how an exposure (hazard) affects a system and how this exposure may be internal or external (represented by exposure being partially located in the external environment (social, economic, and political setting, and related ecosystems)
and partially located within the system, and the sensitivity (impacts) of a system’s exposure to that hazard. These impacts are then related to adaptations in order to understand if the system can absorb the hazard or the hazard causes damage to the system. A system is defined as vulnerable if it cannot adequately adapt to a hazard, whereas a system isn’t vulnerable if it can adequately adapt to a hazard. This represents an either/or condition. The sensitivity element includes the conceptual framework for irrigation water management within it in order to highlight the irrigation scheme is what is exposed to a hazard, what suffers the impacts, and also what must adapt to changing conditions. This vulnerability analytical framework will specifically be used to understand the vulnerabilities of an irrigation scheme to extreme hydrological conditions.

How this vulnerability analytical framework will be used is the discussion chapter of the thesis (Chapter 6) will be divided into exposure, sensitivity and adaptation sections. Exposure will be described using the seven (7) measures of hazardous events. Sensitivity will be described using a set of design conditions for robust institutions that will be formally presented in the discussion section. Finally, adaptations will be described using typology of adaptation characteristics described above. These three concepts will then be used in the conclusion chapter (Chapter 7) to describe the vulnerability of the BVIS.
Figure 5 – Vulnerability Analytical Framework
3 Methodology

3.1 Introduction

The following chapter details the methodology followed in the completion of the research program. This chapter is divided into two sections, which are design and implementation. The design section explains the orientation (mixed methods), the approach (case study) and the research methods used in the completion of this thesis. The implementation section will detail the strategic and tactical decisions made during the completion of the thesis. Ultimately, this methodology chapter details what was planned vs. actually completed and how these processes took place.

3.2 Design

3.2.1 Framework

Creswell (2002) presents a simple framework for research design that generically applies to all research designs. This framework is modified to include the following components: orientation, approach, and methods. Orientation involves a researcher’s scientific paradigms or assumptions for the research, approach outlines the broad procedures followed during the research, and methods details the specific activities completed. In order to visualize this modified framework, it is presented as Figure 6 - Methodology Framework below.
3.2.2 Orientation

3.2.2.1 Scientific Method

Science is a process for understanding the physical and sociological phenomena that surround us. This process can rely on experimentation, counting, measurement, statistical analysis, observation and/or interviews (Stake, 2010, p.11). Different methods are used depending on the philosophical orientation of the researcher. In a broad sense, orientation is a way of thinking about the world and a set of valid approaches associated with those ways of thinking (Pahl-Wostl et al, 2011). Further, a researcher’s orientation refers to “the set of ontological and epistemological assumptions which provide a starting point for scientific enquiry” (Pahl-Wostl et al, 2011, p.839).
3.2.2.2 Ontology and Epistemology

“Ontology is the study of being. It is concerned with ‘what is’, with the nature of existence, with the structure of reality as such” (Crotty, 1998, p.10). In essence, ontology is a way of looking at the world and making sense of sense of it (Crotty, 1998), but a related concept, epistemology focuses on the nature of scientific inquiry (Krauss, 2005). More specifically, “epistemology poses the following questions: What is the relationship between the knower and what is known? How do we know what we know? What counts as knowledge” (Krauss, 2005, p.759)? These two distinct concepts form a researcher’s paradigm.

Both concepts are generally simplified into dichotomies that serve as useful heuristics for beginning researchers. Ontology is dichotomized into realist and idealist perspectives, whereas epistemology is dichotomized into the positivist and constructivist perspectives. The realist perspective is “that the world has an existence independent of us, whereas the idealist perspective is that the world is the result of human cognition” (Gibbs, 2002, p.4). “In the positivist perspective, the object of study is independent of researchers; knowledge is discovered and verified through direct observations or measurements of phenomena; facts are established by taking apart a phenomenon to examine its component parts. Whereas the constructivist view, is that knowledge is established through the meanings attached to the phenomena studied; researchers interact with the subjects of study to obtain data; inquiry changes both researcher and subject; and knowledge is context and time dependent” (Krauss, 2005, p.759). However, the pragmatic orientation of the researcher requires a different philosophical
orientation than simple dichotomizations can offer. This pragmatic orientation will be discussed next.

3.2.2.3 Mixed Methods

As opposed to simple dichotomizations, knowledge claims from a pragmatic perspective arise out of actions, situations, and consequences with the main concern being what works to solve the problem (Creswell, 2002). All that matters to a pragmatist is what works and pragmatism “opens the door to multiple methods, different worldviews, and different assumptions, as well as to different forms of data collection and analysis within a mixed methods study” (Creswell, 2002, p.12). It should be stated that a more idealist/constructivist orientation was used in the completion of this research program in order to learn more about these research concepts to contrast the researcher’s predominantly realist background. However, the ultimate pragmatic orientations of the researcher prevented a complete idealist orientation, so that elements of the realist/positivist orientations were also used in this research program.

3.2.3 Approach

3.2.3.1 Framework

An approach is a process that links design to outcomes (Creswell, 2002), and the case study is but one of several approaches to the completion of scholarly research (Creswell, 1997). Other approaches include: survey, experiment, biography, phenomenology, grounded theory, and ethnography (Creswell, 1997). “The case study is used in many situations, to contribute to our knowledge of individual, group,
organizational, social, political, and related phenomenon as it allows investigators to retain the holistic and meaningful characteristics of real-life events” (Yin, 2008, p.4). According to Yin (2009) it is appropriate when research focuses on more process-oriented and contemporary events under no behavioural control by the researcher. The overall “goal of case study research is to expand and generalize (analytic generalization) and not to enumerate frequencies (statistical generalization)” (Yin, 2008, p.15). A pragmatic decision was made to use a framework for case study design developed by Yin (2008).

3.2.3.2 Design

Case study design involves 6 components: study questions, study propositions, unit(s) of analysis, logical framework, evaluation criteria, and case selection (Yin, 2008). The study questions/objectives were discussed in the introduction chapter. Each case study has a unit of analysis which is the focus of the research study. Some cases involve sub-units of analysis which are referred to as embedded designs whereas holistic designs involve no logical sub-units within a case (Yin, 2008). An example of sub-units of analysis would be farmers within an irrigation scheme. A multiple case study would complete numerous single case studies as part of a combined research program in order to complete analytical generalization. An example of this would be researching several irrigation schemes at one time. Both single and multiple case studies may have sub-units of analysis. Research propositions, an extension of research questions, are the initial hypotheses for the research questions. Logical frameworks present analytical techniques for research questions from data collection
activities (Yin, 2008). Evaluation criteria involve the validity and reliability of the research program. Finally, all of these components inform case study design, but case selection itself is also an important criteria. Cases may be one or more of the following types: critical case, extreme case, typical case, new case, or longitudinal case (Yin, 2008). These components are the considerations of researcher’s during research design, but methods translate process into action.

3.2.4 Research Methods
3.2.4.1 Interviews

Research methods are the techniques that researcher’s use to gather information. Several methods were used as part of this research program. Interviews allow researchers to understand the thoughts, feelings, intentions, and perceptions of an actor in a given situation (Patton, 2002). Interviews can be unstructured, unstructured, or hybrids of these types. The unstructured interview “offers maximum flexibility to pursue information in whatever direction appears to be appropriate, depending on what emerges from observing a particular setting or from talking with one or more individuals in that setting. Most of the questions will flow from the immediate context” (Patton, 2002, p.342). Structured interviews list specific questions or issues to be explored in the course of an interview beforehand. In these situations, interviewers remain free to build a conversation, but the subject areas are predetermined. Additionally, questions can be open of closed depending on whether the choice(s)/response(s) have been predetermined for the respondent. Questions can be on a variety of topics including: experience and behaviour, opinion and values, feelings, knowledge, senses, and
background/demographics (Patton, 2002). It is important to note that no matter the interview format or questions that “the quality of the information obtained during an interview is largely dependent on the interviewer” (Patton, 2002, p.340).

3.2.4.2 Focus groups

“Focus groups make particular use of group dynamics. They consist of small groups of people who are brought together by a moderator to explore attitudes and perceptions, feelings and ideas about a specific topic. The three distinctive and vital points about focus groups are that: there is a focus to the session, with the group discussion being based on an item or experience about which all participants have similar knowledge; particular emphasis is placed on the interaction within the group as a means for eliciting information; and the moderator’s role is to facilitate the group interaction” (Denscombe, 2007, p.178). Groups are typically 6 to 10 people with similar backgrounds who participate in an interview for one to two hours. The object is to get high-quality data in a social context rather than solving problems or making decisions. Social context reflects that participants hear each other’s responses. This allows for refinement of comments that would not occur otherwise (Patton, 2002). It is crucial to remember that “the power of focus groups resides in their being focused” (Patton, 2002, p.388).
3.2.4.3 Document review

There are several types of documents which can be reviewed in the completion of research including: letters, memos, reports, newspaper articles, and census data amongst others (Denscombe, 2007). Vast amounts of data are held in these documents which makes document review a potentially cost efficient means for data generation (Denscombe, 2007). All forms of documentation discussed above are text-based, but visual data, pictures and movies, are also extremely useful as they provide visual cues for field notes during data analysis (Denscombe, 2007). “Documents prove valuable not only because of what can be learned directly from them but also as stimulus for paths of inquiry that can be pursued only through direct observation and interviewing” (Patton, 2002, p.294). Such stimulus for other methods is a means of triangulating data across all research methods.

3.2.4.4 Observation

“Observation offers the social researcher a distinct way of collecting data. It draws on the direct evidence of the eye to witness events first hand” (Denscombe, 2007, p.206). Systematic and participant observations are the two main kinds of observation used in the social sciences (Denscombe, 2007). Whereas systematic observation is linked with the production of quantitative data and the use of statistical analysis, participant observation produces qualitative data used originally by anthropologists to understand processes and culture (Denscombe, 2007). Participant observation is defined as “the method in which the observer participates in the daily life of the people under study, either openly in the role of researcher or covertly in some disguised role,
observing things that happen” (Becker and Geer, 1957, p.28). Information is gathered by the researcher through their participation and experience within the study setting allowing in-depth insights to be gained that wouldn’t occur otherwise (Denscombe, 2007).

3.3 Implementation

3.3.1 Strategic Decisions

3.3.1.1 Deductive/Inductive

The research orientation was predominantly qualitative but using a more mixed methods orientation allowed for strategic and tactical decisions to be more pragmatic in nature. As opposed to a pure qualitative approach using inductive thinking, this research project used deductive thinking, which is one of the major reasons why this research was defined as having a mixed methods orientation. For example, a framework for irrigation water management was used to guide all research questions associated with explaining irrigation water management. Three months was spent in the field, but lack of previous experience in irrigation water management necessitated having a theory to guide the investigation. Perhaps with more time in the field and experience, a more inductive approach could have been used. A pragmatic orientation allowed for a deductive approach to be used while still striving for a constructivist epistemology centering the inquiry on understanding research objectives from the mindset of local individuals.
3.3.1.2 Pilot Testing

Pilot testing is a trial run of the instruments for each research method that will be used in a research program prior to study completion (Patton, 2002). Interviews were conducted with government officials, university professors, local NGO officers, and farmers prior to conducting the study at BVIS. These interviews allowed for contextual factors to be understood making questions more locally grounded. Pilot testing was also a very useful technique for gathering documents locally that weren’t available in any other fashion. The library at the Bunda College of Agriculture also served a valuable source of documentation. A visit was also conducted to a local irrigation scheme near Lilongwe upon arrival in order to observe a functioning irrigation scheme. This visit was conducted with a facilitator familiar with irrigation in Malawi and this allowed for numerous questions to be asked in order to understand the smallest details of this irrigation scheme.

3.3.1.3 Sequence of Action (Following Schedule)

Upon arrival at the irrigation scheme, the water schedule for the scheme was provided from scheme management. This schedule detailed which tertiary canals were to receive water on a given day, which allowed for the schedule to direct attention of the researcher to exactly where water was being managed. The schedule rotated across branch canals, which provided availability for using branch canals as a sub-unit of analysis. However, the decision to have no sub-units of analysis was made and to keep the irrigation scheme as a whole as the only unit of analysis. Due to the schedule,
research methods were applied equally across the entire irrigation scheme, which allowed for a holistic picture to be developed of research concepts.

3.3.1.4 Perspective on System

**Top-Down**

Upon arrival at the scheme, initial understanding of how the scheme operated was provided by the cooperative and scheme management. Additionally, the irrigation systems itself from a physical perspective was framed from a top-down perspective. Starting at the headworks and following the canal system to where it drains into wetlands adjacent to Lake Malawi, the scheme was understood from a big-picture perspective at first. Water distribution and maintenance schedules were provided by scheme management which provided an understanding of water management at the scheme. It was assumed prior to initiating research that water was managed by scheme management so it seemed logical to direct attention at this area of the scheme.

**Bottom Up**

Focus on the irrigation scheme was switched from top-down to bottom-up when water was followed from main canals down to the farmer plots where water is ultimately used. At this point, after having followed water to its end point, it seemed logical to invert focus to the farmer’s perspectives upward. Water was then traced back to the headworks of the scheme. However, an extensive amount of time was spent at the farmer level of the irrigation scheme because water is managed at the tertiary level by
farmers themselves. Approximately two thirds of the time spent in the field was spent with farmers as their understanding became the predominant focus of the research.

3.3.1.5 Sampling Strategy

**Purposeful Sampling**

A purposeful sampling strategy was used in the conduct of most interviews and focus groups. “Perhaps nothing better captures the difference between quantitative and qualitative methods than the different logics that undergird sampling approaches” (Patton, 2002, p.230). “In purposeful sampling, you decide the purpose you want informants to serve, and you go out and find some” (Patton, 2002, p.230). As the schedule was used as the point of entry (sequence of action) to the scheme as a whole, interviews were predominantly conducted with farmers receiving water on a given day. This purposeful sampling strategy targeted farmers in order to understand how water was managed at the tertiary level based on current conditions.

**Convenience Sampling**

Additionally, as the scheme was fairly large and it took extensive time (approximately two hours) to transit from one side to the other when trying to follow the water distribution schedule, this allowed for convenience sampling to be completed. Convenience sampling may be defined as a sampling strategy where respondents are at the convenience of the researcher with no attempt made for an accurate representation of a sample population. Convenience sampling allowed for individuals that were encountered during scheme transits to provide information to inform the
research. Therefore, sampling was conducted from both a purposeful and convenience perspectives in the conducting of predominantly structured interviews and focus groups.

3.3.1.6 Triangulation

Triangulation is the combination of methodologies in a research study with a view towards greater accuracy of results. Denzin (1978) further identifies four basic types of triangulation: theory, methodological, investigator, and data. Theory triangulation was not completed during this research program. Methodological triangulation involves using multiple methods to gather data. Investigator triangulation involves using several researchers in the completion of an investigation. Investigator triangulation will be discussed in the research assistant sub-section below. Finally, data triangulation involves cross-checking across time, space and persons, which could loosely be characterized as a purposeful sampling strategy and is described elsewhere in this methodology section. All forms of triangulation were used except for theory triangulation in this thesis.

3.3.1.7 Research Assistant

A research assistant was hired to assist in the completion of this research program. The research assistant predominantly assisted with translation between English and Chichewa (local language) during the completion of interviews and focus groups. For investigator triangulation, the research assistant for this research program was provided notebooks similar to the researcher and requested to keep notes of all interviews, focus groups, and observations during the completion of the research
program. This second set of notes was predominantly recorded after the completion of interviews and focus groups as the research assistant completed all translation during discussions. Notes include sketches, ethical considerations, memos, interview summaries amongst other useful data. Selection of the research assistant also proved extremely beneficial due to their command of soft skills and interviewing techniques. Numerous interviews could not have been conducted without the skills of the research assistant. Finally, the research assistant proved extremely valuable as a sounding board for ideas while in the field. Many of the strategic and tactical decisions were derived through discussion with the research assistant.

3.3.2 Tactical Decisions

As the research project had a mixed methods (pragmatic) orientation, all tactical decisions flowed from goal of whatever worked best for research. Some decisions had long-term consequences, such as observing and recording water levels upstream of the headworks every morning prior to walking to the tertiary canal receiving water that day. Other decisions had more short term consequences, such as choosing to capitalize on what is termed “bank day” at the irrigation scheme where a substantial number of farmers were meeting with local bank officials which allowed for bulk convenience sampling. Other tactical decisions including not taking the same route to different locations in the irrigation scheme in order to cut different transects across the irrigation scheme. This decision allowed for a greater variety of observations while in the field. Additionally, while completing the first interviews on water management at the tertiary level, a survey of locks on gates located at the tertiary level was completed. The added
time to complete the survey was minimal and provided interesting results on maintenance procedures. Taking extensive notes and recording personal memos was a practical decision in that it was only way to accurately recorded thoughts and feelings on the research to be retained for a later time. For example, an audio recording of thoughts and observations was recorded while walking back from the end of the scheme which allowed for a two hour running dialogue on observations and thoughts. These recording have proven to be one of the most valuable research techniques allowing for a re-emergence back into the research setting away from the scheme. Finally, visiting locations such as the mill on site when there was no objective specifically associated with this visit. Visiting the mill allowed to experience what locals experience and to understand the processing process. All tactical decisions were goal-oriented in a pragmatic orientation.

3.4 Summary of Research Methods

During the fieldwork numerous interviews and focus groups were completed. A total of 68 separate interviews were conducted along with nine focus groups. Both interviews and focus groups varied in length from 10-15 minutes up to an hour. These interviews and focus groups were conducted in Malawi with irrigation professionals (government officials, university professors, and NGO staff), farmers, extension officers, cooperative staff, and cooperative committee members. All interviews and focus groups were conducted in Chichewa (local language) through the translation of a research assistant. A total of 60 interviews were conducted at the irrigation scheme with 30 interviews conducted specifically with farmers and 20 interviews with cooperative
officials (staff, management, committee members). The remaining interviews conducted at the irrigation scheme were with local politicians, government officials and local community members. Focus groups took place with an average of 5-10 individuals per hour-long session. Eight focus groups were conducted directly with farmers at their respective tertiary canal in order to understand water distribution at this level of the irrigation scheme. The remaining focus group was conducted with the water management sub-committee in order to understand water management from a top-down perspective.
4 Case Study

This case study chapter details the relevant background information gathered before, during, and after the completion of fieldwork in Malawi. This chapter discusses three components of the SES framework, which are: Social, Economic, and Political Setting (Section 4.2); Related Ecosystems (Section 4.3); and Irrigation in Malawi (Section 4.4). The decision to eliminate/modify the Users variable and replace it with irrigation in Malawi will be discussed in the relevant section below (Section 4.4). All material presented is derived from interviews and both primary and secondary sources of literature. This chapter provides a relevant understanding of the greater environment surrounding the Bwanje Valley Irrigation Scheme (BVIS) and the BVIS itself in order to assist in the description of the BVIS (Research Objective #1).

4.1 Case Selection

This case was selected for study due to several reasons. First, the BVIS is a large-scale irrigation scheme that has only been in operation for a short period of time. Due to the fact it was a large-scale scheme, reports and documentation were available that could be used in order to better understand the operation of the system. Also, farmers that had been at the scheme since the beginning could be directly interviewed in order to gain a holistic understanding of the life of the scheme. Second, the BVIS was located in an area that could be accessed relatively easy and safe accommodation could be secured. Third, the BVIS is an irrigation scheme that has been struck by floods and droughts, which provided detailed information on how it has responded to these stressors in the past. Finally, in-country support in Malawi had previous research
experience with the BVIS and recommended the site as a suitable location for completing intended research.

4.2 Social, Economic, and Political Setting

4.2.1 Politics

Malawi was first settled during the 10th century and was part of the Maravi Empire. Malawi remained under native rule until 1891 when it was colonized by the British. The British ruled the country until Malawi became an independent nation in 1964. Malawi then became a single-party state under the presidency of Hastings Banda until he was ousted from power in 1994. Since 1994, the Government of Malawi has been a multi-party democracy (CIA, 2010). The current President of the Republic of Malawi is His Excellency Ngwazi Dr. Bingu wa Mutharika who was elected to his second presidential term in 2009. He and his party the Democratic Progressive Party (DPP) were first elected to office in 2004 (ADBG, 2011). The President of Malawi is both the chief of state and the head of government. Executive power is exercised by the government, legislative power is vested in both the government and the National Assembly and the judiciary is independent of the executive and the legislature. The legislative system comprises a 46 member cabinet named by the President. The legal system is a mixture of common law and customary law. Administratively, Malawi is made up of 28 districts and three regions (Central, Southern, and Northern) (UNDP - Malawi, 2011).

At the local level, local government is a traditional authority system, which is made up of a hierarchy of group village headman and village headmen underneath a traditional authority who represents all headmen. The traditional authority system is
hereditary whereas headmen may inherit their positions or be elected by village councils. Traditional authorities receive a salary from the district commissioner’s office and have a staff of messengers and clerical assistants who help them with administration. The main administrative duties of local government are to allocate land and resolve disputes (NKC, 1994). The BVIS has one traditional authority, 4 group village headmen, and 14 village headmen in the surrounding area.

4.2.2 Population

According to the Malawi 2008 Population and Housing Census, the population of Malawi is 13,077,160 (NSO of Malawi, 2008). More current estimates state that the population is 15,879,252 (CIA, 2010). The population estimates for the main cities of the country are presented below in Table 6 - Urban Population Centers (Malawi Embassy to Japan, 2011). Local statistics were not made available during the research or located within the census report, but using the Dedza district (district within which BVIS is located) data local conditions can be generally described. For the Dedza district, the average population growth rate is 2.6 percent while the population density is 172 people per square kilometre in a total land area of 3,624 square kilometres. Therefore, the total population for the Dedza district is approximately 623,000. No recent population statistics were made available for the area surrounding the BVIS.
<table>
<thead>
<tr>
<th>City</th>
<th>Population (in Millions)</th>
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</thead>
<tbody>
<tr>
<td>Lilongwe</td>
<td>1.897</td>
</tr>
<tr>
<td>Blantyre</td>
<td>0.999</td>
</tr>
<tr>
<td>Mzuzu</td>
<td>0.853</td>
</tr>
<tr>
<td>Zomba</td>
<td>0.670</td>
</tr>
</tbody>
</table>

Table 6 - Urban Population Centers (Malawi Embassy to Japan, 2011)

4.2.3 Economy

According to a 2003-2004 Poverty Reduction Strategy Paper annual update report for the International Monetary Fund (IMF) report, around 52.4 percent of the population is below the national poverty line and 22 percent live in extreme poverty (GoM-IMF, 2005). Approximately 83 percent of the population is characterized as rural poor and about 63.7 percent of their total income is realized from the agriculture sector. This sector also accounts for 39 percent of GDP and 90 percent of its export earnings. Exports are predominantly tobacco, sugar and tea, which account for 80 percent of these earnings (GoM-IMF, 2005) while maize, rice, pulses and groundnuts make up a large portion of the remaining crops produced (NKC, 1994).

4.2.4 Religion

According to the 2008 census, approximately 82.7 percent of the population is Christian with the Roman Catholic Church and the Church of Central Africa (Presbyterian) making up the largest Christian groups. Around 13 percent of the population is Muslim with Jews, Rastafarians, Hindus and Baha’is making up the
remaining 4 percent of the population (CIA, 2010). No local statistics were made available.

4.2.5 Health

Life expectancy in Malawi is 51.7 years with an infant mortality rate of 81.04 deaths/1000 live births. There is a high adult rate of HIV/AIDS infection with an estimated 920,000 adults (or 11 percent of the population) living with the disease in 2009. There are approximately 51,000 deaths a year from HIV/AIDS. This translates into approximately 250 new infections every day and 70 percent of the hospital beds in Malawi being occupied by HIV/AIDS victims. There is also a very high degree of risk for major infectious diseases such as food or waterborne diseases, vectorborne diseases, water contact diseases, and animal contact diseases (CIA, 2010).

4.2.6 Education

The literacy rate in Malawi is 62.7 percent (CIA, 2010). Approximately, 28 percent of those children of school age were attending school at the time of the 2008 census. Primary education in Malawi is not compulsory, but 5 years are provided at no cost to all children in Malawi (CIA, 2010). The primary school system is 8 years while the secondary school system is 4 years (EUSM, 2011). There are a number of universities in Malawi for advanced education. No local statistics were made available.
4.3 Related Ecosystems

4.3.1 Geography and Geology

Malawi is nicknamed the “warm heart of Africa” and this nickname emphasizes the warm nature of the Malawian people, but also the geographic position of Malawi within the African continent. Malawi is a landlocked country located in southeast Africa. It is bordered by Zambia to the northwest, Tanzania to the northeast, and Mozambique on the east, south and west. Additionally, the country is separated from Tanzania and Mozambique by Lake Malawi (CIA, 2010). Please refer to Error! Reference source not found. (Worldatlas, 2011a) and Error! Reference source not found. (Worldatlas, 2011b) for cartographic representations of the country. The total area of Malawi is 118,484 sq. km which is 79 percent land and 21 percent water (CIA, 2010). Topographically, there are three major geographical zones in Malawi. The rift valley extends along Lake Malawi from the north to the Shire valley in the south. Both the plateau and mountainous regions are in the north of the country with altitudes between 750-1400m and peaks as high as 3000m (Van Straaten, 2002; McSweeney et al, 2008). Geologically, “Malawi is largely made up of igneous and metamorphic rocks of the Basement Complex of Precambrian age. Parts of the country are covered by Karoo strata and by Cretaceous igneous and sedimentary rocks. Alluvium occurs along Lake Malawi” (Schluter, 2008, p.158). The groundwater level in the study area was measured at a depth of 92 metres at the study site (NKC, 1994, p.I-3-15).

At the regional/local level, the study area can be characterized as being divided into an area with rolling plateaus with inland valleys and isolated hills along with almost flat lowlands near the lakeshore. The BVIS is located right next to Lake Malawi. The
plateau covers the western area with isolated hills of 600-1500 metres in height. Four rivers originate from this plateau and flow eastward. The rivers incise the escarpment capturing small streams as they travel towards the lake. The lowlands lie immediately adjacent to the plateau and river gradients in this area are on the order of 1/200 to 1/500. There are seasonally inundated depressions (dambos) where traditional agriculture was practiced prior to the creation of the BVIS. Regional and local maps of the study area are presented below as Figure 9 - Regional Map (NKC, 1994) and Figure 9 - Local Study Area (NKC, 1997).

Figure 7 – Map of Malawi within Africa (Worldatlas, 2011a)

Figure 8 - Map of Malawi (Worldatlas, 2011b)
Figure 9 - Local Study Area (NKC, 1997)
4.3.2 Temperature

“Malawi has a tropical/sub-tropical climate, which is relatively dry and strongly seasonal. The warm-wet season stretches from November to April, during which 95 percent of the annual precipitation takes place. The annual average rainfall varies from 725mm to 2,500mm with Lilongwe having an average of 900mm, Blantyre 1,127mm, Mzuzu 1,289mm and Zomba 1,433mm. A cool, dry winter season is evident from May to August with mean temperatures varying between 17 and 27 degrees Celsius. A hot, dry season lasts from September to October with average temperatures varying between 25 and 37 degrees Celsius. Humidity ranges from 50 percent to 87 percent for the drier months of September/October and wetter months of January/February respectively” (DCCMS, 2011). No local temperature statistics were available.

4.3.3 Rainfall

As opposed to temperature records, which weren’t readily available, an incomplete set of rainfall data from two distinct stations for a cumulative period of 10 years was procured in order to understand local conditions. This 10-year period coincides with the length of time that the BVIS has been in operation. Please refer to Table 8 - Mtakataka Policy Airway Rainfall Data (MAFS, 2010a) and Table 9 - Mtakataka EPA Station Rainfall Data (MAFS, 2011b). The data in these tables are millimetres of rain accumulated over a 24-hour period added together to yield a monthly total. This data shows there are two distinct seasons with the bulk of the rains coming between December and March while dry conditions are experienced during the winter months in the middle of the year. The magnitude of rainfall on a monthly basis was described
above, but now it is necessary to describe the characteristics of specific precipitation events. A description of local rainfall events is that it typically lasts for a period of a few days and then it rains again a few days or a week later. This cycle repeats itself throughout the rainy season. An examination of a limited number of daily precipitation totals revealed magnitudes as low as a few millimetres, but as high as 70 millimetres. This rainfall directly leads to river discharge described below.

4.3.4 River Discharge

The major rivers in the study area are the Nadzipulu River, Nakaingwa River (tributary of the Nadzipulu River), Namikokwe River, Nadzipokwe (tributary of the Namikokwe River), Livulezi River, Bwanje River, and Liwadzi River. Although, other rivers in the study area have higher discharges, the Namikokwe River was chosen as the source for the BVIS and discharge data in units of cubic metres per second for this river from a gauge located just upstream from the BVIS is presented in Table 7 - Namikokwe Combined Monthly Discharges (NKC, 1997). Total drainage area and exact length of the Namikokwe River could not be located.

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
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<th>Jul</th>
<th>Aug</th>
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Table 7 - Namikokwe Combined Monthly Discharges (NKC, 1997)
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<td>Aug</td>
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<td>Sep</td>
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<td>Nov</td>
<td>12.2</td>
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<td>Dec</td>
<td>186.2</td>
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<td>Total</td>
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Table 8 - Mtakataka Policy Airway Rainfall Data (MAFS, 2010a)
<table>
<thead>
<tr>
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<th>2008</th>
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<td>Jan</td>
<td>212.7</td>
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<td>Feb</td>
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<td>19.0</td>
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<td>142.4</td>
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<td>97.2</td>
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<td>48.2</td>
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<td></td>
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<td></td>
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<tr>
<td>Sep</td>
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<td></td>
<td>5.0</td>
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<td>Oct</td>
<td>32.9</td>
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<td>129.5</td>
<td>67.2</td>
<td>30.5</td>
<td>93.0</td>
<td></td>
<td></td>
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<tr>
<td>Nov</td>
<td>32.2</td>
<td>46.9</td>
<td>109.8</td>
<td></td>
<td></td>
<td>319.8</td>
<td>319.8</td>
<td>45.8</td>
<td>245.1</td>
<td>218.0</td>
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</tr>
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</table>

Table 9 - Mtakataka EPA Station Rainfall Data (MAFS, 2010b)
4.3.5 Climate Change

Multiple sources describe that since the 1950s the rains received annually haven’t changed drastically. However, the rains are starting and finishing earlier, which causes great difficulty for farmers who try to plant according to the historical seasons. The intensity of rainfall is also changing yielding more flash floods and a greater number of dry spells. Major drought events have occurred across Malawi with relatively recent events including a drought in 1991/92 and flood in 1998/00. Low-lying areas such as Lower Shire Valley and some localities in Salima (near BVIS) and Karonga are more vulnerable to floods than higher grounds (DCCMS, 2011). The UNDP Climate Change Country Profile for Malawi makes the following statements on how Malawi’s climate has changed and is predicted to change under climate change:

1. “Mean annual temperatures have increased by 0.9°C between 1960 and 2006 with an average increase of 0.21°C per decade although year-to-year variability in rainfall makes it difficult to identify long term trends. This increase in temperature has been most rapid in summer.

2. The mean annual temperature is projected to increase by 1.1 to 3.0°C by the 2060s, and 1.5 to 5.0°C by the 2090s.

3. Observations of rainfall and extreme hydrological conditions over Malawi do not show statistically significant trends.

4. Projections of mean rainfall do not indicate substantial changes in annual rainfall, but consistently project increases in the proportion of rainfall that falls in heavy events” (McSweeney et al., 2011, p.2).
4.4 Irrigation in Malawi and Background of the Bwanje Valley Irrigation Scheme

The Users category was removed from the conceptual framework due to research limitations related to time. User characteristics are important, but the decision was made early on in the research to focus on the governance, resource, and resource units variables within the system. However, it is still important to understand how irrigation has affected local populations. In order to understand irrigation the following section provides background information on irrigation in Malawi as a whole and background information on the BVIS in order to provide a deeper understanding of the irrigation scheme itself.

4.4.1 Irrigation in Malawi

4.4.1.1 Broad Irrigation Characteristics

“Irrigated land in Malawi includes formal irrigation schemes operated by government and private estate owners, as well as land along stream banks, in low-lying areas of residual moisture, and in wetlands cultivated by small-scale farmers in the dry season. The oldest traditional irrigation method used in the country is the watering can. It is probably the cheapest and simplest technology and hence most widely used by smallholder farmers in self-help schemes” (Njoloma et al., 2009, p.2). The Malawi Department of Irrigation classifies irrigation schemes as: small schemes with a gross area of less than 50 ha; medium schemes with 50 to 500 ha; and large schemes which includes those over 500 ha in size. Schemes may be formal, semi-formal, or informal depending on management structure. Informal schemes are developed by the farmers themselves with limited or no technical design input whereas in semi-formal schemes
farmers receive technical support along with formal establishment of a management organization. Finally, formal schemes encompass all schemes planned, designed and built by trained professionals according to technical standards (FAO-Aquastat, 2011).

Total irrigated land in Malawi has been estimated to be as little as 28,000 hectares up to 680,000 hectares. These estimates group formal, semi-formal, and informal schemes together to varying degrees. Estimates of informal schemes range as low as 6,500 up to 480,000 hectares whereas formal or semi-formal schemes range as low as 28,000 hectares up to 200,000 hectares. The common estimate for the potential irrigated area (not limited to wetlands) is between 250,000 and 500,000 hectares (Ferguson and Mulwafu, 2005). Most of the potentially irrigable land lies in the plains along the shores of Lake Malawi, the Lake Chilwa Plain, the Lower Shire Valley and the flood plain of the Limphasa River in Nkhata Bay (FAO-Aquastat, 2011).

4.4.1.2 Irrigation Development

Irrigation development in Malawi can be traced back as far as the 1940s and its evolution can be divided into 4 distinct eras: the government initiated scheme era; the self-help era; the scheme management transfer era and the irrigation for food security era (Wiyo and Mthethiwa, 2008). First, the government initiated scheme era dates to the 1940s with the development of the Limphasa irrigation scheme in the Nkhata Bay District (Njoloma et al., 2008). The Sugar Corporation of Malawi (SUCOMA), now called Illovo sugar, was established in 1965 (Njoloma et al., 2009). Second, a total of 16 schemes were developed by government between 1968-1979 along the shores of Lake Malawi, and around Lake Chilwa and in the Lower Shire. These large bureaucratic
schemes were funded by donors and were settled by farmers from all over Malawi. They focussed on rice and had the goals of poverty reduction, and increased household income, employment and exports. Third, as large, bureaucratic irrigation schemes the world over became costlier and costlier to run, donors moved out of agricultural water development projects. This left the Malawian government to develop irrigation on its own. During this era, informal schemes were constructed by both government and potential farmers on a community-based scale. Rice was still the main crop produced. Also, Irrigation management transfer (IMT) was the major thrust of the third era for the large schemes whereby the operation and maintenance of schemes were decentralized from government to communities. The reason for this change was the continued costs associated with operating and maintaining these structures. IMT has met with mixed success in Malawi as many farmers struggle to run and maintain the schemes. Finally, in the last era, food security became the dominant issue due to frequent droughts and food shortages. Irrigation was seen as a solution to the problem of rainfed agriculture, and government, donors and NGOs poured resources into small-scale irrigation projects focussed on food security. Numerous technologies (treadle pumps, sprinkler, motorized, river diversions, canalization, drip kits etc) and multiple approaches (free, subsidized, full cost) have been used to combat food insecurity (Wiyo and Mthethiwa, 2008).

4.4.1.3 Legal Framework

The Main legislation concerned with issues of water resources and irrigation are the Water Resources Act of 1969 and the Irrigation Act of 2001. The Water Resources Act of 1969 regulates the control, apportionment and use of all water resources in
Malawi. All abstractions greater than 1000 Litres/day except Municipal use must have a permit. The Irrigation Act of 2001 makes provision for the sustainable development and management of irrigation, protection of the environment from irrigation related degradations, and the establishment of a National Irrigation Board (FAO - Aquastat, 2006).

The main policies are the National Irrigation Policy and Development Strategy and the Water Resources Management Policy and Strategy both developed by the Ministry of Irrigation and Water Development. There have been multiple editions of these policies, but overall the National Irrigation Policy and Development Strategy strives to manage and develop water and land resources in an economically sound and sustainable manner. It also calls for the transfer of smallholder irrigation schemes that had previously been operated by the government to newly formed farmers’ associations, water-user groups, or other local institutional structures. The policy goal of the Water Resources Management Policy and Strategy is sustainable management and utilization of water resources in order to provide water of acceptable quantity and quality through integrated water resources management. Ultimately, both of these policies were implemented to reform access to water resources and to transfer governance of water resources to local community-based institutions (FAO - Aquastat, 2006).

4.4.2 Evolution of Irrigation in the Bwanje Valley

4.4.2.1 Traditional Agriculture

Before an irrigation scheme was constructed at the site of the BVIS, farmers practiced traditional agriculture in the wetlands (dambos or low-lying areas within
floodplains). Farmers would grow rice where water had flooded and/or drained into natural pools. Water supply exceeded demand and therefore could be used without any restrictions in order to grow rice, sugar cane, amongst other crops. All land, water, and other resources were governed at the community level with customary traditions guiding its distribution. Farmers reported to traditional authorities in their respective areas, but this all changed with donor financed irrigation, which took the land away from farmers in order to develop irrigation in the Bwanje valley.

4.4.2.2 Mtandamula Self-Help Irrigation Scheme

The first constructed irrigation scheme in the Bwanje Valley was the Mtandamula irrigation scheme. It was built in 1987 and was located in the area closest to Lake Malawi in the current BVIS. Farmers grew rice with irrigation water supplied by a gravity system taking surface water diverted from the Namikokwe River. A diversion bank was located at the southwest end of the scheme for dual purpose of flood protection and reservoir. Total area of the scheme was 230 hectares divided into 20 fields further divided into 20-37 plots per field. Funding for the project was provided for by the European Economic Community (EEC). Government planned and designed the system while construction was completed by farmers (NKC, 1994).

4.4.2.3 Bwanje Valley Irrigation Scheme

Donor financing for a project in the Bwanje valley was guaranteed by the Japanese government through the Japanese International Cooperation Agency (JICA) in 1990 (Veldwisch et al., 2009). A feasibility study was carried out in two phases
between 1992 and 1994. Phase I assessed the irrigation potential in a 2,500 km² region around the BVIS and selected the 5 most suitable sites. Phase II conducted detailed surveys of the 5 selected areas in order to determine the most feasible alternative (NKC, 1994). From the Feasibility Study, it was concluded that the BVIS was the most technologically and economically feasible alternative (NKC, 1997).

A design study for the BVIS was conducted between 1996 and 1997, which included: farmer participation and self-management operation and maintenance; construction of intake weir to stabilize water supply; construction of primary, secondary, and tertiary canals; partial land levelling of 47.8 hectares with remainder to be completed by farmers; construction of drainage canals; construction of roads and 13 village boreholes; and the construction of four rice mills (design study). A total of 800 hectares of irrigable area would be developed with 230 hectares from the existing Mtandamula irrigation scheme and 570 hectares of newly developed area (NKC, 1994).

The BVIS irrigation scheme was completed in January 2000 at a total cost of US$15 million. Similarly to the Mtandamula irrigation scheme, a permanent river diversion structure was built along the Namikokwe River with protective dikes constructed along the course of the main canal with a large settling basin constructed to de-silt the water before it enters the scheme. Additionally, a series of lined (secondary) and tertiary (earthen) canals was networked across the irrigation scheme. Finally, farmers were made responsible for water management at the tertiary level with scheme management responsible for acquisition, allocation and distribution above the outlet (Veldwisch et al., 2009).
Beginning in November 2005, a JICA financed rehabilitation plan was carried out costing US$320,000 for headwork rehabilitation, settling basin rehabilitation, main canal relocation, land levelling and land re-allocation. Numerous governance and resource system changes were desired after farmers had an opportunity to work with the system for several seasons. Extensive rehabilitation was required of the headworks due to portions of the dike being flushed away and the destruction of a 100 metre section of the main canal by floods in 2002 and 2003. After the rehabilitation, the BVIS is comprised of 2 primary canals servicing 5 secondary canals.

The BVIS was originally run by the government through the extension officers in order to assist farmers with the operation and maintenance of the irrigation scheme, but in 2003-2004 farmers were approached by the regional officials from the MAFS and told that they had to organize themselves into an association or a cooperative. Farmers made the choice to form a cooperative as it was determined that this was the better choice for them and the cooperative was officially registered with the MIT in 2004. The decision to form a cooperative took place in 2003-2004 and the cooperative was officially registered with the Ministry of Industry and Trade in 2004. In order to form the cooperative, initial working capital in the form of a loan from ‘One Village One Product’ (OVOP) was provided to the cooperative. OVOP is a strategic Japanese regional development program which works at the village level in order to develop one local product into a competitive product on both the domestic and global markets, which will hopefully improve the standard of living for residents in the local village where it’s produced. For the BVIS, this product was and still is rice (Gondwe, 2011). These funds
allowed the cooperative to buy processing equipment including one rice sheller and one maize sheller which continues to generate substantial revenue for the cooperative.
5 Results

This chapter presents the results of the research program completed at the Bwanje Valley Irrigation scheme (BVIS) during the fall of 2010 in Malawi, Africa. All results are presented according to the modified social-ecological systems framework described in the literature review chapter of this thesis. The Resource System section (Section 5.1), the Governance System section (Section 5.2), and the Resource Units section (Section 5.3) are used to describe the structure and function of the BVIS (Research Objective #1). These sections are situated within an external environment described in the case study chapter (Chapter 4). The Interactions section (Section 5.4) and a portion of the Outcomes Section (Section 5.5) are used to explain the process of irrigation water management at the BVIS (Research Objective #2). Finally, the remaining portion of the Outcomes section (Section 5.5) is used to describe system adaptations that have occurred at the BVIS (Research Objective #3). System Vulnerability (Research Objective #4) will be discussed in the Discussion Chapter (Chapter 6) and Conclusion Chapter (Chapter 7).

5.1 Resource System

This section focuses on the resource system of the irrigation scheme organized according to the abstraction, distribution and drainage functions synonymous with the input, transformation, and output processes of all open systems. This section describes the function and structures – canals and associated infrastructure that most think of when visualizing an irrigation scheme - not the specific processes for how they are operated and maintained.
5.1.1 Functions

5.1.1.1 Abstraction

The first activity in an irrigation scheme is acquiring water. At the BVIS this is completed by damming (barricading) the Namikokwe River in order to divert its waters into the irrigation scheme. A parabolic-crested weir performs this function. Additionally, two scouring sluice gates are used to flush sediment, which may have settled in front of the intake gates to the scheme. This activity is necessary as the Namikokwe River has a high sediment concentration. Bar racks cover the intake gates and are used to capture trees and other floating debris in the river before they can clog the system. Please refer to Appendix B: Plate 1 - Parabolic Crested Weir; Plate 2 - Parabolic Crested Weir; Plate 3 - Scouring Sluice Gates; Plate 4 - Scouring Sluice Gates; Plate 5 - Intake Gates for a pictorial description of these structures.

An underground pipe conveys water from the intake gates to the settling basins. Three settling basins allow sediment to settle out of the input water before being distributed across the scheme. These basins work in parallel which allows for maintenance or flushing of these basins to be performed without interrupting the flow of water to the irrigation scheme. The settling basins are the last structure in the abstraction process before water is outputted to the distribution system. All sediment settled out of the intake water is outputted back to the Namikokwe River just downstream of the headworks. Please refer to Appendix B: Plate 6 - Settling Basins; and Plate 7 - Settling Basins for a pictorial description of these structures.
5.1.1.2 Distribution

The first structure in the distribution sub-system is the headrace. The headrace is the canal which connects the outputs of the settling basin to the gate structure. The gate structure splits the flow between the two main canals in the system. The main canals in the system are named old main canal (M1) and new main canal (M2). Please refer to Appendix B: Plate 8 - Gate Structure for a pictorial representation of this structure. Please refer to Figure 11 - Map of Bwanje Valley Irrigation Scheme for a graphical representation of the BVIS.

From the gate structure, two main canals convey water to a system of branch canals. The first main canal (M1) delivers water to branch canals M1BC1, and M1BC2 while the second main canal (M2) delivers water to branch canals M2BC1, M2BC2, and M2BC3. Please refer to Table 10 - Main and Branch Canal Network for a table outlining how the canals are divided within the BVIS.

<table>
<thead>
<tr>
<th>Canal</th>
<th>Old Area (210 hectares)</th>
<th>New Area (590 hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Canals</td>
<td>M1 (old main canal)</td>
<td>M2 (new main canal)</td>
</tr>
<tr>
<td></td>
<td>M1BC1</td>
<td>M2BC1</td>
</tr>
<tr>
<td>Branch Canals</td>
<td>M1BC2</td>
<td>M2BC2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M2BC3</td>
</tr>
</tbody>
</table>

Table 10 - Main and Branch Canal Network

The naming structure for these branch canals derives from the structure of the irrigation scheme before the rehabilitation. Prior to the rehabilitation there was only one
primary canal (M1 – old main canal) and three secondary canals (BC1, BC2, and BC3). The new main canal (M2) was constructed during the rehabilitation and now supplies water to the upper halves of BC1 and BC2 while supplying all the water to BC3. M1 (old main canal) now delivers water only to the lower halves of BC1 and BC2, but no longer supplies water to BC3. Water is delivered to the branch canals by a series of bifurcation structures. These structures divert the water from the main canal into the branch canal where water is being delivered. Operation of these structures is controlled by two manual gate valves that direct water to either the main or the branch canal. There are a total of five bifurcation structures with two located on M1 and three located on M2. Please refer to Appendix B: Plate 9 - Primary Canal; Plate 10 - Primary and Secondary Canals; Plate 11 - Tertiary Canal; Plate 12 - Bifurcation Structure; and Plate 13 - Bifurcation Structure for pictorial descriptions of these structures.

After the water is diverted from the main canal, water is conveyed via the branch canal to the turnouts. These turnouts are the structures that control the delivery of water to the tertiary canals. A manual center gate located on the branch canal regulates the water level, so that an intake gate to the tertiary canal can be opened. The intake gate delivers water to the tertiary canals which subsequently delivers water to the farmer’s fields. These turnout gates can be located on the left or right (facing downstream) sides of the branch canals depending upon the side of the branch canal that the tertiary canal is located. Please refer to Appendix B: Plate 14 - Turnout Structures for a pictorial representation of these structures. The current system has 148 tertiary canals, which is an increase from 132 tertiary canals prior to the rehabilitation. Please refer to Table 11 -
**Branch and Tertiary Canals Network** for a description of the secondary and tertiary canals within the irrigation system.

<table>
<thead>
<tr>
<th>Branch Canal</th>
<th>No. of Tertiary Canals to Left Side</th>
<th>No. of Tertiary Canals to Right Side</th>
<th>Total No. of Tertiary Canals</th>
<th>Area (hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1BC1</td>
<td>13</td>
<td>7</td>
<td>20</td>
<td>117</td>
</tr>
<tr>
<td>M1BC2</td>
<td>11</td>
<td>9</td>
<td>20</td>
<td>86</td>
</tr>
<tr>
<td>M2BC1</td>
<td>15</td>
<td>16</td>
<td>31</td>
<td>173</td>
</tr>
<tr>
<td>M2BC2</td>
<td>19</td>
<td>14</td>
<td>33</td>
<td>146</td>
</tr>
<tr>
<td>M2BC3</td>
<td>16</td>
<td>28</td>
<td>44</td>
<td>276</td>
</tr>
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<td><strong>Total</strong></td>
<td><strong>74</strong></td>
<td><strong>74</strong></td>
<td><strong>148</strong></td>
<td><strong>798</strong></td>
</tr>
</tbody>
</table>

Table 11 - Branch and Tertiary Canals Network (NKC, 2008)
Figure 11 - Map of Bwanje Valley Irrigation Scheme
Delivery of water to the field canals is controlled by a system of gates similarly to tertiary canals. As opposed to tertiary gates, wooden blocks or earth/sediment impede flow from the tertiary canals to the field canals. To direct flow into a field canal, the block gate is removed and a small earthen dam or a wooden block is inserted across the tertiary canal to direct the flow of water into the field canal. Please refer to Appendix B: Plate 15 - Field Canal Structures and Plate 16 - Field Canal Structures for pictorial representation of these structures.

At the field level, there are 5 plots per field. All plots are 0.2 acres in size with five plots equalling 1 field for a total area of 1 acre. All farmers create field canals within their fields/plots, but these are modified or constructed by farmers depending on their own desires for field and water management. No comprehensive survey of the number of fields and plots was provided or surveyed during the completion of the research program.

5.1.1.3 Drainage

The drainage system for the BVIS is a series of canals similar to the distribution canals except that they are all earthen channels. They also operate in reverse order of distribution canals as their function is to remove water from the system. Field level drains collect or capture above-ground surface runoff and below-ground interflow respectively through gravity. Drainage canals are termed primary, secondary, and tertiary drains similarly to the irrigation canals (Vandersypen, 2007). Tertiary drains convey water to the secondary drains at the branch canal level, which connect to the primary drains at the scheme-wide level. The primary drains after collecting all the water
in the system output drainage water out of the irrigation scheme to Lake Malawi which is located approximately 500m from the edge of the irrigation scheme. No hydraulic control structures are located on the drainage canals. Please see Plate 17 - Primary Drain; Plate 18 - Secondary Drain; Plate 19 - Tertiary Drain; and Plate 20 - Tertiary Drain for pictorial representation of these structures.

5.2 Governance System

5.2.1 Organizations

5.2.1.1 Government

Several organizations are involved in the governance and management of water at the BVIS. The two dominant government organizations involved in the field of irrigated agriculture in Malawi are the Ministry of Agriculture and Food Security (MAFS) and the Ministry of Irrigation and Water Development (MIWD). While the MIWD is described as the mother of all irrigation in Malawi, the MAFS is the major user of the technology MIWD provides. Although the MAFS is more directly involved in the day-to-day running of the BVIS, there is a symbiotic relationship amongst these organizations for the successful operation of the irrigation scheme. The MAFS will be explained first.
1) Ministry of Agriculture and Food Security (MAFS)

Purpose

According to the Commonwealth of Nations (CN, 2011a), the objectives of the MAFS are:

1. To attain and sustain household food self-sufficiency and to improve the nutritional status of the population;
2. To expand and diversify agricultural production and exports;
3. To increase farm incomes;
4. To conserve the natural resources base;
5. To formulate agricultural policies, legislation and regulations with stakeholder participation;
6. To generate and disseminate agricultural information and technologies;
7. To regulate and ensure quality control of agricultural produce and services; and
8. Monitor and manage the food security situation.

Configuration

The objectives described above are achieved through a hierarchy of departments spread out across Malawi. At the top of the hierarchy is the MAFS followed by Agricultural Development Divisions (ADD), then Rural Development Projects (RDP), and finally Extension Planning Offices (EPA). For the BVIS, the Lilongwe ADD, the Dedza RDP, and the Mtakataka EPA are the departments that exert direct influence on the BVIS. There are a total of 8 ADDs spread across the Northern, Central, and
Southern regions of Malawi. There are 3 RDPs located within the Lilongwe ADD including the Dedza RDP. There are a total of 10 EPAs located within the Dedza RDP. The Mtakataka EPA is further divided into 16 sections with three of those sections located at the BVIS. These three sections are synonymous with the branch canals (BC1, BC2, BC3 – both new and old main canal sections) of the irrigation scheme.

Each EPA is staffed by an Agricultural Extension Development Officer (AEDO). AEDOs report to supervisors at their local EPA, who in turn report to District Agricultural Development Officers (DADOs) located at the RDP level, who then in turn report to officials at the Ministerial level. There is supposed to be a total of three AEDOs located at the BVIS, but at the time the research was being completed there were only two as the AEDO for BC3 had recently quit. It was anticipated to be a difficult position to fill as this area of the scheme is located far from the scheme office and there was shortage of fuel and motorbikes which is how AEDOs travel throughout the irrigation scheme. The specific roles of the AEDOs will be discussed later in this chapter, but for now only the structure of staff at the irrigation scheme is explained.

2) Ministry of Irrigation and Water Development (MIWD)

Purpose

As stated above the MIWD is responsible for ensuring that the MAFS gets what it needs with respect to irrigation technology. This responsibility is the outcome of the organization’s objectives listed on the Commonwealth of Nations (CN, 2011b) website, these four main objectives are:
1. Increasing availability and accessibility of water and sanitation services for socio-economic growth and development;
2. Achieving sustainable and integrated water resources management systems;
3. Developing the institutional capacity of the water and sanitation sector; and
4. Increasing agricultural productivity and enhancing food security through irrigation development.

Configuration

Unlike the MAFS, the MIWD has no one stationed at the BVIS, but there are officials stationed at the district level. In order to mitigate this deficiency, all AEDOs are trained in irrigated agriculture.

5.2.1.2 Cooperative

As discussed in the case study chapter, the cooperative at the BVIS didn’t always exist, but was established as it was believed it could best achieve the interests of the farmers. In order to understand this organization, its purpose and configuration are presented below.

Purpose

Like any organization, the cooperative was created in order to achieve mutually beneficial outcomes or objectives. The objectives as listed in the cooperative’ constitution is the following:
o “Source funds by selling of shares and entry fees from its members;

o Encourage its members to grow different varieties of crops;

o Purchase farm inputs such as hybrid seeds, fertilizer and pesticides and sell them to its members at cheaper prices;

o Find markets for its members to sell their produce (locally & Internationally);

o Ensuring that its members are harvesting high quality produce buy teaching them new methods of farming;

o Provide loans and other farm inputs such as seeds and fertilizer to its members so as to produce bumper yield;

o Encourage its members to protect natural resources such as land by using new approved methods of farming;

o Representing its members to the government, and other NGOs on their needs

o Ensuring that its members are paying back loans and that they are saving other amounts of money;

o Granting powers to its members on farming through training;

o Have a car for carrying produce to the market and other goods from the market to the cooperative;

o Have a warehouse for storage of seeds and other goods for the cooperative;

and

o To do everything possible in order to achieve the above mentioned objectives” (BVIPMCSL, Unknown).
These objectives translate into farmers describing their cooperative as being responsible for the buying and selling of rice produced at the irrigation scheme, providing inputs to farmers at lower prices and loans where needed, along with the operation and maintenance of the irrigation scheme itself (NKC, 2008). There are many committees that make up the structure of the cooperative and each of these is presented in turn below.

Configuration

1) General Committee

The General Committee is made up of 27 farmers from the scheme. A total of 9 farmers from each branch canal are on the committee in order to have representation from across the scheme. The 27 members of the general committee are voted into office by their fellow farmers in elections held every 3 years. All 2067 farmers within the irrigation scheme vote in these elections. The elections for the general committee were last held in the fall of 2009.

2) Executive Committee

The executive committee is responsible for managing the day-to-day affairs of the cooperative. This executive committee is made up of 9 members who hold the following positions:

- President
- Vice-President
Secretary
Vice-Secretary
Treasurer
Finance Committee Members (x4)

The members of the executive committee are elected from the general committee. Same term lengths apply to both the general and the executive committees of the cooperative with the elections for the executive committee held shortly after those for the general committee.

3) Sub-Committees

The following sub-committees are located within the cooperative:

Water Management sub-committee
Disciplinary sub-committee
Agricultural sub-committee
Land Allocation sub-committee
Marketing sub-committee
Finance sub-committee

4) Water Management Sub-Committee

While all sub-committees are important, water management was the major focus of this thesis. Therefore, the configuration of the Water Management Sub-Committee is presented in order to better understand this sub-committee. Water Management at the
BVIS is completed primarily through the actions of the water management sub-committee. This sub-committee is comprised of members of the general committee of the cooperative elected to terms of similar length to the cooperative itself. However, similar to all affairs within the BVIS, operation and maintenance of the physical structures of the BVIS is completed with advising and training provided by the AEDOs. There are supposed to be 7 members of the water management sub-committee. These numbers translate into two farmers from BC1, two farmers from BC2, two farmers from BC3, and one chairman. However, one member of the water management sub-committee recently vacated their position leaving the committee one member short. How the sub-committee accomplishes water management will be described in the interactions section.

5) Cooperative Staff

The cooperative also employs 14 people in order to achieve its objectives. The following paid positions are located at the cooperative:

- Book Keeper;
- Clerk Officer;
- Stores Clerk;
- Cashier;
- Machine Operators (multiple positions);
- Guards (multiple positions); and
- Ground Labourers (multiple positions).
5.2.1.3 Farmers

1) Farmers

Purpose

The farmers are the main reason for the existence and continuation of the BVIS as without farmers that toil the soil there would be no irrigation scheme. The goals of the farmers are to grow crops in order to make money, so that they have a viable livelihood strategy. There are other ways in the surrounding area of the BVIS to earn a living, but the easiest way to make money is to be a farmer at the irrigation scheme. There is no other goal but livelihood for why farmers farm at the BVIS.

Configuration

The scheme presently has 2067 farmers from 14 villages surrounding the scheme. There are 983 male farmers and 1084 female farmers. Presently, this is the upper limit for the number of farmers within the scheme, and this number stays constant as when one farmer leaves another farmer joins right away replacing the vacating farmer. This pattern of no vacancies for spaces as farmers within the scheme was characteristic of turnover at the scheme for the past several years. The number of farmers from the different villages is presented below in Table 8 - Village Farmer Representation. The date of information listed in this table is unknown.
<table>
<thead>
<tr>
<th>Number</th>
<th>Villages</th>
<th>Number of Farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Madziansatsi/Bwanali/Nsolo</td>
<td>127</td>
</tr>
<tr>
<td>2</td>
<td>Fole</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>Mlongoti/Kafulama/Kambuluma/Maiwaza</td>
<td>123</td>
</tr>
<tr>
<td>4</td>
<td>Mdulambale</td>
<td>114</td>
</tr>
<tr>
<td>5</td>
<td>Mchanja</td>
<td>296</td>
</tr>
<tr>
<td>6</td>
<td>Ndongwe</td>
<td>102</td>
</tr>
<tr>
<td>7</td>
<td>Mwasinja/Msunduzeni/Mathemba/Njirika/Mlangeni/Chatata/Tidyenao/Kaongo/Mkwaira</td>
<td>168</td>
</tr>
<tr>
<td>8</td>
<td>Mkondolire</td>
<td>226</td>
</tr>
<tr>
<td>9</td>
<td>Chatewa/Michembo</td>
<td>170</td>
</tr>
<tr>
<td>10</td>
<td>Mthembanji</td>
<td>220</td>
</tr>
<tr>
<td>11</td>
<td>Mbangali</td>
<td>84</td>
</tr>
<tr>
<td>12</td>
<td>Bwanamakowa</td>
<td>66</td>
</tr>
<tr>
<td>13</td>
<td>Galuanenenji</td>
<td>146</td>
</tr>
<tr>
<td>14</td>
<td>Dziko/Kasakala/Chitukula</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>2067</strong></td>
</tr>
</tbody>
</table>

Table 8 - Village Farmer Representation (NKC, 2008)

2) Farmer Clubs

**Purpose and Configuration**

Farmers’ clubs are responsible for the management of operation and maintenance at the tertiary level. These clubs are made up of an executive that comprises the following positions: president, vice-president, secretary and treasurer. Some farmers
referred to president and vice-president as chairman and vice-chairman respectively. All these positions are elected for terms of 3 years in length. However, the 3-year terms for farmer clubs are only for fields used during the rainy season, whereas farmer clubs would be elected on a season-to-season basis for the dry season. Farmers’ club elections take place after the elections of the cooperative. The last elections took place in January 2010. Elections for farmer clubs in the dry season take place in June following the allocation of land in the dry season. The role of these clubs will be more specifically explained in the mechanisms sub-section of the governance system section. Farmers’ clubs in one form or another have been responsible for water management and maintenance at the tertiary level since the beginning of the irrigation scheme.

5.2.2 Mechanisms

5.2.2.1 Roles

1) AEDOs

The BVIS actually has four AEDOs at the irrigation scheme, but one of these AEDOs is the scheme manager for the irrigation scheme. The scheme manager doesn’t supervise a specific section rather supervises the AEDOs that supervise the specific sections located at the BVIS. Additionally, one AEDO is appointed Deputy Scheme Manager, but this individual has responsibilities for a section within the BVIS. The main responsibilities of the scheme manager and the AEDOs are to create work plans for the BVIS and advising farmers on both agriculture and irrigation. This advising is completed through demonstrations of new techniques and technologies at the field-level in order to show farmers how they can benefit. The Advising and training of farmers extends to the
governance and management of the cooperative at the BVIS in order assist this organization with achieving its objectives. The cooperative at the BVIS will be described in a separate section. While the scheme manager has responsibilities for advising and training of all farmers, AEDOs have responsibilities for advising and training for their respective BCs.

2) Executive Committee and General Committee

There are two committees that govern and manage the BVIS. At the end of the day, the general committee is similar to the board of directors of an organization responsible for oversight, but actual management is completed by the cooperative executive committee. The executive committee is responsible for managing the day-to-day affairs of the cooperative. The role of the executive committee was described by farmers as running the business and the sharing of profits through dividends. Additionally, the executive committee is responsible for assisting farmers with loans for inputs.

3) Cooperative Sub-Committees

There are 5 existing and 1 defunct sub-committees at the BVIS. The Water Management sub-committee was already described in the preceding section, but its role is to manage water at the BVIS. The disciplinary sub-committee is responsible for settling disputes or conflicts amongst members of the cooperative. The agricultural sub-committee is responsible the training and monitoring of farmers in the use of new methods of cultivation. The land allocation sub-committee was established to reallocate land during the rehabilitation, but was closed after its task was completed. The
marketing sub-committee is responsible for searching for inputs to sell to members, and searching for markets for the rice produced within the cooperative. Finally, the finance committee is responsible for ensuring the cooperative maintains good financial standing.

4) Cooperative Staff

Each of the cooperative’s staff has a specific role to assist the cooperative in achieving its objectives. The bookkeeper is responsible for the accounting of the cooperative, which entails keeping track of revenue and expenses in order to balance the budget for the organization. The clerk officer is responsible for the collection of water fees, annual fees and share fees that all farmers are responsible for paying. In addition to this responsibility they conduct market research in order to locate markets for the products produced at the BVIS. The store clerk is responsible for the recording of deliveries of inputs to the cooperative and shipments of product output from the cooperative. Additionally, they assist in the processing or products including milling, grading and packing. Finally, they provide detailed reports on these items to the Clerk Officer. The cashier is responsible for the collection of fees from farmers for shares, water fees, annual fees and inputs (fertilizer and seeds). Water guard at the BVIS are responsible for water distribution during the rainy season. They ensure that primary and secondary canal gates are open in order to direct flow to the required tertiary canal, and also to communicate the schedule to farmers receiving water on a given day.
5) Farmers and Farmers’ Clubs

At the field level, farmers are responsible for the operation and maintenance of the distribution and drainage system. This function is accomplished through the establishment of a Farmers’ club with the associated positions described above. Within a farmer’s plot or field, the farmer themselves are responsible for operation and maintenance. The exact functions that farmers’ and farmers’ clubs perform are discussed below in the interactions section.

5.2.2.2 Rights

1) Executive Committee

According to the cooperative constitution the members of the executive committee have the following rights:

- “The responsibility of running day-to-day operations of this cooperative; and
- Elected members shall hold their positions until next elections” (BVIPMCSL, Unknown).

2) General Committee

According to the cooperative constitution the members of the general committee have the following rights:

- “All the powers of the cooperative shall be in the hands of this meeting according to the laws of this cooperative;
Conduct annual general meeting;
Receive reports; and
- form the Executive committee
- from the sub committees
- financial reports from cooperative staff
- from the Auditors
Conduct elections” (BVIPMCSL, Unknown).

3) Farmers

According to the cooperative constitution all farmers have the following rights:

- “Attend all the general meetings of the cooperative;
- Vote during elections;
- Aware of all the operations of the cooperative;
- Elect or get elected on any position;
- In association with other members to call for meetings (emergency);
- Benefit from all operations of the cooperative; and
- Withdraw membership” (BVIPMCSL, Unknown).

5.2.2.3 Rules

1) Executive Committee

According to the cooperative constitution the executive committee must follow the following rules:
o “No member shall be allowed to contest for any position if he/she has served for 9 consecutive years. He/ she can contest again only when 2 years have elapsed.

o If one member has been dismissed from his position within the year, his/her position shall be replaced 3 weeks after his dismissal;

o There shall be monthly meetings for the committee. Chairperson or his vice shall be responsible to call for a meeting;

o All discussions shall be written down and be kept by the secretary.

o The executive committee shall comprise the following positions: chairperson, vice-chairperson, secretary and vice-secretary;

o Elections for positions shall be held on same day or within one week of general committee elections;

o All financial transactions and cheques for the cooperative shall be signed by the following people; Chairperson, Secretary and treasurer;

o Ensure that all financial records have been checked by Auditors at the end of the year; and

o Provide well detailed report to the general committee” (BVIPMCSL, Unknown).

2) General Committee

According to the cooperative constitution the executive committee has the following rights:
o “Conduct annual meeting 3 months after all the financial records are closed;

o Give two weeks written notice of meeting by writing including: date, time, place and agenda for the meeting” (BVIPMCSL, Unknown).

3) Farmers

According to the cooperative constitution all farmers must follow the following rules:

o “Raise capital for the cooperative by the purchase of shares;

o Pay any amount of money if asked to do so by the cooperative;

o Accepts facts that the majority has agrees plus those that the board can make;

o Attend all the meetings called by the Management;

o Encourage other farmers to join the cooperative; and

o Perform roles as required.

o Any member shall be dismissed from the cooperative if he/she offends laws of the cooperative. 2/3 of the total members shall determine the dismissal of this member on a general meeting. He/she shall not be dismissed from the cooperative without trial.

o Satisfy following membership requirements
  - Small scale farmer who lives within the area that this cooperative represents
  - Who is above 18 years if age and have good manners
Who can be able and willing to use the advices given to him by cooperative

Who does not have crime with the government.

Follow Entry/Exit Requirements

- Death, or failure to have a single share in cooperative
- Dismissed for breaking laws of the cooperative at general meeting with two-thirds quorum or trying to bribe court” (BVIPMCSL, Unknown).

5.2.3 Regime (Levels)

With numerous organizations and their associated actors with defined roles involved in the governance, management, and operation of the BVIS, it is necessary to describe in greater detail how all of these units fit together into a governance regime. There are three levels in the governance regime of the BVIS. Level 1 (constitutional level) is the government of Malawi and its associated Ministries who influence the BVIS through national level policies, laws, and regulations. These policies determine the strategic direction that Level 2 (collective-choice level) organizations and actors must follow in order to manage the BVIS. Level 2 is the AEDOs, and the cooperative, who together directly manage the day-to-day affairs of the irrigation scheme. Government policies are put into practice at the BVIS through the AEDOs. While policies encapsulate the higher level objectives of the government, AEDOs advise and train the cooperative in the proper operation and maintenance of the BVIS. The cooperative was established by farmers in order to further reduce the excludability and subtractability problems inherent in common pool resources. Additionally, the cooperative was
established so that management and governance was implemented by actors directly involved in the BVIS. The cooperative governs and manages through a nested set of organizations/actors as described above. Finally, Level 3 (operational level) is the farmer clubs and farmers within the BVIS. Although farmers may be elected to the cooperative for the most part these actors follow mechanisms established by higher levels in the regime hierarchy. Farmers are tasked with completing operational and maintenance activities. In order to visualize the relationship amongst these multiple levels of governance, Figure 12 - Governance Regime is presented below.
In order to estimate water supply, water guards were asked to describe the fluctuations in water levels referenced to a water gauge located on the headworks. The scale on the gauge measures zero at the crest of the weir and rises to a level of 30 feet.
which is approximately the same level as the inspection bridge. The reason for using a qualitative description of water levels is that no water level records are kept at the BVIS.

Starting in January and working chronologically throughout the course of a typical year, typical rains raise the water level to a level of 18-19 feet. Then over the course of the following week will recede down to a level of 6-7 feet until the next rains come. The water level can reduce to a level of 4 feet if there is an extended period of no rainfall. When it rains again, the water level rises to a level of 18-19 feet or more depending on the amount of rains. On average the level of the river cycles between a level of 6-7 feet and 18-19 feet depending on the frequency of rainfall events. However, large precipitation events produce high level water events or floods on the Namikokwe River and in these cases the water level can rise to above 20 feet and sometimes even approach 30 feet. In 2008, the region experienced a large rainfall event and the water level reached a level of 30 feet touching the underside of the inspection bridge. As the Namikokwe River is predominantly an ephemeral river, water levels exhibit an oscillating pattern rising up and down depending on the magnitude, frequency and duration of rainfall events. The lag time between a storm event and an increase in the level of the river was described as approximately only one hour.

As the rainy season comes to an end, water levels gradually stabilize in the 3-4 foot level area by the end of April. Importantly, a level of 3 feet was described by farmers as still sufficient for farmers to irrigate their crops. As the rainy season has finished, no further rainfall events will contribute water to the river that could be utilized by the BVIS. As time progresses, the water level decreases below the datum (0 feet) to where it is at the height of the weir. When the water level falls below the height of the
weir, the channel behind the weir turns into a pseudo reservoir with the weir operating as a dam. The Namikokwe River is a slightly gaining river which means a small portion of its flow is provided from baseflow or groundwater, which means the water level in the channel - not in reference to the gauge - never falls to zero. With the closing of the sluice gates and the weir functioning as a dam, the water level gets lower and lower as there is a higher demand than available supply for water as the dry season progresses. Depending on the start of the rainy season, water levels will then rise to levels seen in January, and the cycle repeats itself.

5.3.2 Water Delivery

As opposed to water supplied to the headworks of the BVIS, this sub-section focuses on the amount of water delivered to farmers. There is no recording of water levels at the tertiary canal level. The magnitude, frequency, duration, and timing of water delivered to farmers are presented for both the rainy and dry seasons respectively. Qualitative descriptions for the preceding variables were gathered during interviews and focus groups. Data was gathered from farmers. The following descriptions of water delivery generally follow the same pattern described above for the water supply sub-section, which is to be expected as the two are directly related.

5.3.2.1 Rainy Season

All farmers that predominantly rely on irrigation water stated that they receive 90-100 percent of the magnitude of water they were expecting during the rainy season. However, not all farmers in the rainy season rely on water from the canal system.
Numerous farmers stated fields located at the end of tertiary canals rely on drainage water as opposed to irrigation water. It was estimated that approximately 25 percent of farmers rely on drainage water with the remainder using irrigation water. For those farmers relying on irrigation water, it was stated that water was received as scheduled unless flood events occurred which closed the intake gates to the BVIS for a period of time. The duration of water deliveries in the rainy season were on average 10-12 hours in length.

5.3.2.2 Dry Season

All farmers stated that they received 90-100 percent of the water they expect at the beginning of the dry season. However, as the dry season progresses and water levels in the Namikokwe River lower, water deliveries decrease. Farmers stated they received on average 30-40 percent of the water they expect by the middle to end of the dry season. Next, most farmers described not receiving water according to any schedule in the dry season. Farmers expected water to be delivered at a frequency of 7-10 days, but in practice this didn’t occur. When water was delivered, it was delivered for a period of 10-12 hours similarly to the rainy season.

5.4 Interactions

5.4.1 Water Management Process

5.4.1.1 Planning Processes

Planning and decision-making processes for water management at the BVIS are the responsibility of the water management sub-committee. This committee meets on a
frequent basis – no schedule could be confirmed - to review how water is currently being allocated and to plan for how water should be allocated in the future. While planning and decision-making are the responsibilities of the water management sub-committee, when issues are too large or complex then the water management sub-committee requests the assistance from the Agricultural Extension Development Officers (AEDOs). The AEDOs assist them in resolving complicated issues. Additionally, when resolutions are made in these meetings, the input of the executive committee of the cooperative is sought in order to ensure that the objectives of the cooperative are being continually met. There is provision for emergency meetings of the sub-committee in case unforeseen circumstances arise, but no emergency meetings have ever been held according to members interviewed.

5.4.1.2 Organizing Processes

The BVIS operates during both the dry and rainy seasons and as such the structuring and sequencing of activities and roles is slightly different across the seasons. Operation and maintenance are the two functions that water management sub-committee members manage and these will be discussed separately.

Operations

Operations are dictated by the water schedule which details when tertiary canals will receive water. During the dry season, the schedule operates on a 3-day rotation, which means each BC gets water for a period of 3-days. As there are 3 BCs within the BVIS, each one of those areas will get water for 3 days one after the other and then the
cycle repeats. The gate structure along with the bifurcation structures are used to control the flow of water to a specific branch canal in the system. During the rainy season, there is also a 3-day schedule but this schedule rotates water within the BCs on a 3-day basis. Providing water to all BCs is possible in the rainy season as water levels in the Namikokwe River are elevated enough that water can flow freely to all BCs. The gates at the gate structure allow water to flow freely to both M1 and M2. On Sundays in the rainy season, deliveries of water to all BCs are stopped, so that maintenance can be performed at the headworks. The schedule resumes where it left off on the Monday following maintenance of the headworks. The delivery of water according to the schedule is accomplished through coordination and communication activities, which will be described in the next section after maintenance is described.

**Maintenance**

Following the path water takes in the BVIS from source to drainage, the first maintenance task is the removal of debris (i.e. tree branches) that has become trapped by the piers of the inspection bridge and on the intake gates. The second maintenance required is the flushing of sediment that has accumulated in front of the intake gates. This task is accomplished by opening the sluice gates and closing the intake gates, which allows sediment to be flushed downstream. No schedule was provided for the frequency of these tasks. Subsequently flushing of the sedimentation basins needs to be performed on a daily basis during the rainy season and a weekly basis during the dry season. The process for removing sediment trapped in the sedimentation basins is to open one of the three cells at a time and to allow the sediment to be outputted back to
the Namikokwe River. During the dry season the draining of a sedimentation basin cell was observed to take approximately 30 minutes. This allowed for the flushing of sediment and the refilling of the cell. All maintenance at the headworks level of the irrigation scheme is completed by staff of the cooperative.

The distribution system can also become clogged with sediment. Sediment trapped in the primary and secondary canals must be removed by hand with this work completed by ground labourers and farmers. The removal of sediment from the canals occurs approximately three times throughout the course of the rainy season whereas due to decreased water supply it is completed on an as-needed basis in the dry season. In addition to the removal of sediment, weeds clog the distribution canals throughout the growing seasons but especially during the rainy season. Routine maintenance performed by farmers as part of their cooperative responsibilities is to remove weeds from the primary and secondary canals. This routine maintenance ensures the system performs as optimally as possible. Weeding is completed 2-3 times per month for the branch canals and monthly for the primary canals by farmers. Major primary and secondary canal maintenance is scheduled prior to the beginning of each season. Additionally, the drainage system is cleaned by ground labourers in January and February during the rainy season.

At the tertiary level, the farmer’s clubs are responsible for ensuring that maintenance is performed. Especially during the rainy season, weeds need to be removed from tertiary canals at least once per week and more if necessary. This work is completed by the farmer whose land is adjacent to the section of tertiary canal running past their land. Cleaning the tertiary canals is a prerequisite for obtaining water as it is
responsibility mandated by the cooperative’s regulations. It was observed during the field research that water wasn’t allocated to a tertiary canal for the non-performance of maintenance, but after canals were cleaned water was delivered to the canal.

5.4.1.3 Leading Processes

Leading processes are the communication and coordination of resources in order to achieve objectives. As the schedule has already been created, it is the responsibility of the water guards (rainy season) or the water management sub-committee members (dry season), hereinafter described as water distribution officials, to distribute water at the primary and secondary canal levels. These water distribution officials in conjunction with farmers’ clubs are responsible for the distribution of water in both seasons. A typical day at the BVIS according to the schedule commences at 6AM, and at this time the water distribution official would meet farmers at the turnouts scheduled to receive water. Prior to arrival at the tertiary canals, water distribution officials would have gotten the keys for the locks on all tertiary canals that prohibit farmers from taking water out of turn. All keys for a given branch canal are stored on large key rings, which allows for the opening and closing of the gate structure (M1 or M2) along with the locks for the intake gates at the tertiary level. There are key rings for water guards and sub-committee members in addition to one set of spares stored in the office. All primary and secondary canal gates would be opened/closed so that water flows to the proper canal prior to meeting farmers at the tertiary level to distribute water.

Water distribution meetings are held at the tertiary canal level each morning in order for a plan to be established on how water will be distributed. Depending on the
number of fields/plots (varies between rainy and dry seasons) and the availability of water, water will be distributed to a certain number of fields/plots for a specific period of time throughout the scheduled day. The decision of how to distribute water at the tertiary level is a field-level decision with farmers and water distribution officials completing it collectively in most cases. In order to better understand water management and its outcomes, several water distribution circumstances are presented in the interactions section of this results chapter.

5.4.1.4 Controlling Processes

In order for operation and maintenance at the scheme to occur smoothly there are several control activities which farmers and the cooperative along with its staff must follow or participate in. The control activities were described in the literature review as monitoring, sanctioning and conflict resolution and those activities will now be described. Water distribution officials monitor conditions by being present at the tertiary canal where water is distributed according to the schedule and observing throughout the course of the day that things are progressing as scheduled. Sanctioning entails the right to withhold water until maintenance activities are performed or levying a fine when a farmer steals water. Fines may also be levied according to the rules of the cooperative when farmers don’t perform maintenance. Due to a scarcity of water in the dry season it is necessary to sanction farmers at times for stealing water.

Conflict resolution is an extremely important role of several actors within the scheme. Tertiary leaders, water guards, sub-committee members, and the cooperative committees are all responsible for resolving conflicts. Conflicts amongst farmers arise
because of the subtractive nature of water resources. What one farmer uses cannot be used by another farmer. Farmers stated that people fight and quarrel over water all the time in the dry season, which can be observed directly by following where the water is flowing within the scheme. The level of conflict is raised to the extent that people carry knives and sleep at their land when it is their turn to get water. When farmers cannot resolve conflicts amongst themselves including discussion with tertiary leaders then water guards and sub-committee members are responsible for resolving disputes. Water distribution officials are able to resolve most conflicts due to the level of respect their position has, but these officials do on occasion use officials from other BCs to assist where needed. If conflicts still cannot be resolved then disputes are brought to the cooperative for resolution. Local politicians may be brought in to assist the cooperative in resolving conflicts. It was communicated by local politicians that the level of conflict rises during the dry season necessitating them to assist in the resolution of issues on a frequent basis. This conflict resolution process was described as a two-level process starting with water distribution officials and ultimately to the cooperative with assistance of traditional authorities in cases which cannot be resolved at the lower level.

5.5 Outcomes

5.5.1 Production

The cooperative produces maize in the dry season and rice in the rainy season. Farmers produce approximately 8 bags of maize in the dry season for household consumption. In the rainy season, farmers produce approximately 40-60 bags of rice. The cooperative is unable to buy all the rice produced by the farmers, but has in recent
years purchased approximately 20 bags at a price of 3200-3500K/bag. The remaining rice produced by farmers is sold to vendors for a price of 2200-2500K/bag. These prices reflect rice sold at the end of the rainy season when supply is high. When supply is low towards the end of the dry season, farmers can sell rice for 3200-3500K/bag to vendors. However, most farmers cannot wait till the end the dry season to sell their rice, which translates into lower purchase prices for their rice.

5.5.2 Water Management Circumstances

The water management process was described above and from the research it was determined that this process resulted in several water management circumstances or outcomes. A total of four water management circumstances were observed and these circumstances are described below.

5.5.2.1 Circumstances #1

On several occasions farmers at tertiary canals located throughout the system were observed receiving water as scheduled and working together when it came to water management below the outlet. In order for this to occur, a water distribution official and farmers would have met to plan, decide, and sequence water distribution for the scheduled tertiary canal. Water delivered was divided amongst the total number of fields in the tertiary canal according to the time available for watering. For example, if 10 fields (including plots) are located on a tertiary canal then the last 5 fields would be filled for half the available time and the remainder filled in the time leftover. All fallow plots in a tertiary canal are skipped as these fields don’t require water. Although water
distribution is scheduled day to begin at 6AM, it was stated that distribution started later than this on occasion. In this event, water would be delivered to all fields based on the available time remaining in the day. In order for this circumstance to work (starting on time or late), farmers would have to have previously agreed to work together with respect to water management. Numerous farmers stated that they met with their farmers’ clubs at the beginning of the season in order to come to an agreement on how to manage water throughout the course of the season. Farmers explained these discussions allowed them to avoid problems in most cases throughout the season, but when quarrels arose then those would be brought before the water distribution official for resolution. This circumstance details how water is distributed when everything in the system is functioning as planned and there is enough water available. When water isn’t available will be discussed in the next circumstances.

5.5.2.2 Circumstance #2

On two separate occasions during the peak of water scarcity it was observed that a local politician received all the water in the BVIS. Quite literally all the water abstracted at the headworks was distributed to one tertiary canal. It was described that all the local politician has to do in order to receive water is to call the BVIS and their request is granted. It should be noted that local politicians are not farmers in the BVIS, but rather due to their positions have plots assigned to them through an unknown process. On one occasion a cooperative general committee member was observed monitoring the delivery of the water to the local politician’s plot. When asked why water was being delivered to this local politician’s plot, he responded that respect for the
position this individual held required everyone to allow them to receive water. This individual also responded that his crops were dying at the very moment he was delivering water to the crops of the local politician. This person wanted water for their own crops, but couldn’t force the delivery of water to their plot. In one occurrence water was delivered to a tertiary canal within the branch canal scheduled to receive water while on another occasion water was distributed to a branch canal where water wasn’t scheduled. This circumstance reveals that water may be delivered to those with position and power.

5.5.2.3 Circumstance #3

In circumstance #3, the water schedule is followed, but doesn’t provide enough water to all farmers. In order to remedy this situation, farmers pay water distribution officials 200-500K in order to have water delivered to their plots. Numerous farmers stated that bribery is a common occurrence at the BVIS especially in the dry season or generally when water supply is low. How the bribery takes place is that a farmer and the water distribution official will arrange to meet at night when farmers receiving water have left for the day. The bribe will take place and water will then be directed to the farmer paying the bribe’s plot. In this circumstance farmers scheduled to receive water leave with water flowing to their field and return with water flowing to their field, but end up receiving less water than expected. For this circumstance to work, water can only be delivered to tertiary canals on the secondary canal receiving water. It is not impossible, but highly unlikely that water would be moved to another branch canal due to the time requirements (travel time) to make such a circumstance possible. When water supply is
at its lowest, it was explained that water goes to those farmers that pay for it except when a person in power requests water be delivered to their plots first.

5.5.2.4 Circumstance #4

Finally, farmers described that they steal water in order to supply water to their crops because they do not have positions or money. The stealing of water was described as predominantly occurring at night because once the sun goes down the fields are less closely monitored as during the day. How this occurs is that the water being delivered to another farmer’s plot is stopped or more covertly a channel or pipe is installed that diverts water out of that individual’s plot. As there are no pumps, water can only flow by gravity to adjacent plots when stolen. It was described that depending on topography and the farmers involved, water can be moved in all directions even across drainage canals or to fields on the other side of a tertiary canal. Cover of darkness allows farmers to get the water that they need when it is not being supplied as required.

5.5.3 Adaptation

5.5.3.1 Tactical Adaptations

Field Water Management

Tactical adaptations refine actions in order to improve performance without changing how things are done. The first tactical adaptation to be presented is the improvement of water management by farmers within their plots or fields. The management of water at the field-level was described as one of the most important activities that farmers perform in the course of growing their crops. Field water
management was explained as the construction of channels and boundaries in order to
direct and contain water within a farmer’s plot. Training on field water management has
been completed by extension officers and a group of 40 farmers were sent to Tanzania
for training on water management amongst other topics, but field water management
still isn’t being performed as instructed. Successful farmers described that field water
management is the most important activity to their success. Field water management
allows them to keep their fields moist even when the headworks are closed for a week
due to high water levels in the rainy season, but it was described that this is the root
cause of most of non-successful farmer’s problems. Potential problems with field water
management may reside in the fact that farmers must switch plots between the rainy
and the dry seasons, but all farmers are faced with this situation and some can adapt
while others cannot. This tactical adaptation is planned in that all farmers have been
trained across the entire scheme on how things should be done. This adaptation is a
long-term policy in that it is intended to be followed by all farmers across the entire
scheme, but it is reactive to the fact that farmers haven’t really understood the
importance of this activity when they began farming at the BVIS. Therefore the BVIS is
still trying to educate or re-educate farmers 10 years after the scheme was created.
However, as described above field water management is still not performed adequately,
which causes many farmers great difficulty.

Land Levelling

Another tactical adaptation revealed during the research was a land levelling
project completed during the rehabilitation. Level land allows for the more efficient
distribution of water within a farmer’s field. All land was supposed to be levelled following the construction of the BVIS as detailed in the design report for the scheme. However, it was not completed as scheduled after the construction. This necessitated the adaptation project to level the approximately three-quarters of all fields not levelled. This planned adaptation was reactive to concerns expressed by farmers with respect to land levelling not being completed. The work is now almost complete with positive long-term implications for all farmers in that they no longer have great difficulties in directing water throughout their fields and plots. Some plots are still not level, but those cases were described as few and far between. This adaptation was completed throughout the entire scheme and was intended to improve performance for the long term.

Flooding

The final tactical adaptation was the system’s response to two floods that struck the scheme in 2002 and 2003. These floods overtopped the channels and destroyed a segment of the M1 canal located within BC1. The section of canal damaged was approximately 100m long. Temporarily a wooden canal was built to deliver water to BC2 and BC3, but a permanent strategic adaptation was implemented during the rehabilitation. The permanent tactical adaptation was to use a section of M1BC1 to convey water replacing the damaged section, which was permanently damaged. This planned adaptation was reactive to damage from the flooding and is a long-term but localized adaptation. This adaptation has allowed for BVIS to continue distributing water in this section of the scheme. This adaptation was completed during the rehabilitation
This adaptation was capable of withstanding an elevated water event in 2008 when water levels reached a 30 foot level just underneath the inspection bridge.

5.5.3.2 Strategic Adaptations

Land Reallocation

The following adaptations are strategic in that they attempt to improve the effectiveness of processes and actions by changing how they are completed. After the initial design of the irrigation scheme up till the rehabilitation, it was observed that some farmers could have up to 5 acres of land when farmers were only supposed to have 1 acre. Originally, all farmers that worked on the construction of the original scheme were allocated land; this was actually a condition for being given land in the first place. The allocation of land for the original scheme was the responsibility of traditional authorities. However, some traditional authorities had more land than others, which allowed them to allocate a larger portion of land to farmers in their respective areas. In some of these instances, farmers that received 5 acres of land weren't capable of keeping up with maintenance responsibilities due to the amount of work required for all their land. This led to less maintenance being performed than required. Additionally, some farmers would rent out their excess land, which provided them an unfair advantage as compared to farmers with only one field. An agreement was signed by 1601 farmers on March 4, 2006 reallocating the land within the irrigation scheme. The work towards creating this agreement was assisted by the land allocation committee and JICA during the rehabilitation of the scheme. This strategic program affected the governance system,
and was planned in reaction to an internal condition. This adaptation was widespread across the scheme and for the long-term.

**Switching Crops**

Another strategic adaptation was switching from producing rice in the dry season to producing maize. This change was prompted due to less water being available than anticipated from the external environment after the creation of the BVIS. The crop water requirements for rice were more than was available in the dry season. The switch to maize was completed at the beginning of the dry season in 2001. This long-term, scheme wide change was reactive to changing water availability, but a planned change implemented by extension officers. The change modified the resource system and the policy implementing the change was a new requirement for all farmers. The switch to maize was accepted by farmers as all farmers described maize as life in Malawi. Maize is the staple food crop produced for consumption, whereas rice is the cash crop produced at the BVIS.

**Water Schedule**

One of the most significant strategic adaptations was the switch from a 4-day to a 3-day water rotation. The original BVIS schedule was designed based on crop water requirements, but it failed to deliver water to all sections of the scheme as needed. There are now no problems during the rainy season with the schedule but there remain problems in the dry season due to increasing water supply issues upstream from the BVIS. A series of small-scale schemes (SSS) were constructed by the government and
are now abstracting water from the Namikokwe River. The change in schedule is a reactive adaptation to externally driven water supply issues. This planned adaptation affects the whole scheme and is intended as a long-term change.

**Command Area Sizing**

The BVIS is 800 hectares in area during the dry season, but only approximately 145 hectares during the dry season. As insufficient water is available for the entire scheme in the dry season, only a small portion of the scheme is used to produce maize in the dry season. Several factors including soil type and soil moisture content are used in determining the amount of land to be planted in the dry season. The determination of the size of the command area for the dry season was described as being a decision made by cooperative officials and the AEDOs. Land is allocated based on demand and predicted water availability. This strategic adaptation is necessitated each dry season by external water supply issues, and is a long-term policy initiative. This proactive adaptation was planned during the design of the scheme and applies to the whole scheme.

**Cropping Calendar**

The BVIS plans to plant rice in early to mid December and maize in May every year. However, the start time of seasons sometimes need to be shifted for various conditions including climate. For example, when rains don’t start in early December as expected, farmers cannot transplant their crops into their fields because there is no water available for irrigation. This delays the planting of rice shifting the cropping
calendar. As long as the rains come later in December or early-to-mid January, farmers stated that serious problems are avoided. It has never occurred, but cooperative officials stated that planting later than January 20\textsuperscript{th} would put the rice growing season in jeopardy because rice requires a lot of water. Rice’s crop water requirements couldn’t allow it to be planted at such a late time in the rainy season when the rains will stop in two months and rice takes 4 months to grow. If the rains started later than January 20\textsuperscript{th}, it was described that maize would be planted in order to salvage the growing season. Additionally, the maize crop planted during the dry season observed was planted in early May but an infestation of mice destroyed many of the crops planted and necessitated planting maize a second time. Every year farmers at the BVIS adjust their planting dates based on water availability. This strategic adaptation is reactive to existing water conditions, and spontaneous to time remaining in the present growing season. This adaptation is short-term in nature and localized in that farmers determine themselves when crops are planted.

5.5.3.3 Transformative Adaptations

BVIS Construction

The first major transformative or systemic change at the BVIS was the construction of the BVIS itself. Farmers described that traditional agriculture was practiced in the area long before the BVIS was constructed. In order to build the BVIS land was taken away from farmers practicing traditional agriculture in the area. The BVIS was a proactive and planned adaptation in order to achieve specific development objectives, but it transformed how agriculture was practiced in the area. It was a long-term project
that affected all agriculture in the local area. It is also the most impactful adaptation at the BVIS as it encompasses and causes all adaptations discussed in this section.

Gov to Coop Scheme

The second major transformation at the BVIS was the transition from a government-led scheme to a cooperative-led scheme. As discussed above, farmers at the BVIS were approached with the choice of forming an association or a cooperative. Farmers made the choice to form a cooperative and this decision changed how the BVIS conducts the management of its affairs. Prior to this transformation all decisions relating to the affairs of the BVIS were made solely by the AEDOs, but after this changed the cooperative is now responsible for decision-making with assistance provided by the AEDOs. This transformation was proactive in that it was a deliberate attempt to improve the governance and management of the BVIS. It was a long-term change that had widespread impacts across the irrigation scheme. Please refer to Table 13- Summary of Adaptations for a characterization of adaptations completed historically at the BVIS.
<table>
<thead>
<tr>
<th>Adaptation</th>
<th>Stress</th>
<th>Level</th>
<th>Type</th>
<th>System</th>
<th>Intent</th>
<th>Timing</th>
<th>Temporal Scope</th>
<th>Spatial Scope</th>
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<tr>
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<td>Internal</td>
<td>External</td>
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<td>Strategic</td>
<td>Transformative</td>
<td>Policy</td>
<td>Process</td>
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<tr>
<td>Switching Crops</td>
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</tr>
<tr>
<td>Cropping Calendar</td>
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<td>X</td>
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<td></td>
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<td>X</td>
</tr>
<tr>
<td>BVIS Construction</td>
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<td></td>
<td>X</td>
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<tr>
<td>Gov to Coop</td>
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<td>X</td>
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<td>X</td>
</tr>
</tbody>
</table>

Table 13- Summary of Adaptations
6 Discussion

6.1 Normal Operating Conditions

6.1.1 Exposure

This chapter discusses the vulnerability of the BVIS (Research Objective #4) as it relates to the three components of the vulnerability analytical framework. This chapter provides the foundation for conclusions presented in the Conclusion Chapter (Chapter 7). The case study chapter and the results chapter Irrigation schemes are constructed for a variety of purposes as described in the literature review chapter. At a practical level, irrigation in the Bwanje Valley (BVIS, Mtandamula, and communal schemes) has allowed farmers to control water to varying degrees enabling agriculture in the dry and rainy seasons. At the national policy level, the BVIS was developed in order to create jobs and to increase food security in Malawi. Both jobs and food production have increased with the BVIS, but the irrigation system still relies on the rains in order to achieve its objectives because water in the Namikokwe River is generated by the rains. Without a dam, only water flowing at any given time in the Namikokwe River is available for abstraction. This water availability directly influences water management at the BVIS as described by the water management circumstances in the last chapter. From the research, it appears that these circumstances arise because of how the water supply interacts with the governance system of the BVIS. It is posited that the current design of the governance system of the BVIS creates the conditions that allow water management to deteriorate with decreasing water supply. In order to explain this progression, the water circumstances will be discussed followed by an examination of the governance system of the BVIS. Together these elements will enable a description
of vulnerability of the BVIS in normal operating conditions, which will serve as a baseline for the discussion in the following section on the institutional vulnerabilities of the BVIS to extreme hydrological conditions.

6.1.1.1 Supply Exceeds Demand

Water circumstances described in the results chapter highlight a pattern of what happens when less water is available to farmers at the BVIS. Circumstance #1 occurs when ideal operating conditions are experienced. Ideal operating conditions means that water supply equals or exceeds water demand. From the research, it appears that this condition only occurs during the rainy season. As described in the result chapters, not all farmers rely on irrigation water in order to water their crops. This occurs because farmers at the tail-end of tertiary canals can direct water from the drainage canals into their plots. Approximately 25 percent of the farmers interviewed during the research stated that they relied on drainage water in the rainy season. Additionally, farmers in the rainy season can also rely on the rains to water their crops. However, not all crop water requirements can be supplanted by rainwater due to the nature of paddy rice farming and its high crop water requirements. These two processes along with increased flows in the Namikokwe River during the rainy season means there is more water for those farmers that need it. In this case a circumstance where supply exceeds demand exists.

This circumstance translates into a sufficient level of water being available to farmers, which increases the likelihood that agreements related to water management can be reached. These agreements would be between the farmers and the water distribution officials at the tertiary level. Agreement means water can be equitably distributed to farmers as discussed in the results chapter (i.e. half of farmers receive
water for half the day and the other half of farmers receive water for the other half of the day). Conflict is reduced in this condition because there is reduced stress on farmers with respect to getting the water inputs needed for their crops because farmers know they will most likely get the water that they need. It cannot be stated under this circumstance that all disagreements are averted, rather it is only posited that increased water supply reduces tension allowing collective action to more readily occur. Corruption and bribery are always present according to farmers, but those negative externalities can be averaged out across all members of the cooperative having a reduced impact than during the dry season. This circumstance can be simplified to supply exceeds demand which allows for collective action to more readily occur.

6.1.1.2 Demand Exceeds Supply

Unlike circumstance #1, the remaining three circumstances occur when water demand exceeds water supply. What was observed is that when water supply exceeds water demand other less cooperative behaviours are exhibited. It is posited that these negative behaviours are due to lack of receipt of water by farmers, which necessitates farmers finding alternative strategies for getting water to their crops before they wilt. These behaviours can be divided into 3 circumstances which are status and power (circumstance #2), bribery (circumstance #3) and theft (circumstance #4).

**Status and Power**

Circumstance #2 refers to water being distributed to those that have elevated positions in the BVIS or the local community. Local politicians, extension staff (AEDOs),
and cooperative executive or general committee members all can get water with the power of the roles they occupy. As presented in the results all it takes is one phone call for a person local politician to receive water as desired. Other mechanisms likely exist for those with positions to receive water such as requesting water from a water distribution official directly, but no interviews can confirm this. What was stated by farmers is that when an individual with power and status requests water then water is directed to that person’s plot without question. This circumstance exists to such a degree that the water schedule can be modified to distribute water to an entirely different branch canal when a request for water is made. These requests subtract available water from the system to individuals that haven’t necessarily even bought shares, paid water fees, or paid annual fees because of the influence their position has in the local community. It was described that extension officers and local politicians have plots within the BVIS illegally whereas cooperative committee members just use their position to influence others. In these circumstances, there are no conflict resolution mechanisms available to farmers as those responsible for conflict resolution are the individuals that are potentially stealing water or allowed the corruption to occur in the first place. Additionally, it was observed that individuals are asked to monitor the distribution of water to ensure that those with status and power receive water as requested. It was stated that those with status and power receive water on a frequent basis across both seasons, but in times of water scarcity those water deliveries have more of a negative effect on the remaining farmers in the system.
Bribery

Circumstance #3 refers to farmers buying water from water distribution officials at a time when it is not their scheduled turn. According to farmers, the cost of buying water out of turn is approximately 200-1000K. Most farmers described this behaviour as occurring at night when no other farmers were around. The process was described as the farmer buying water and the water distribution official would meet at the tertiary canal of the farmer. Money would be exchanged and the water distribution official would allow the farmer to irrigate their crop. In order for this to occur, water being delivered to another farmer would be stopped – remembering the water distribution official directed water to this plot earlier in the day – and re-directed to the farmer buying the water’s plot. In this circumstance, farmers originally distributed water would leave for the day while receiving water and return the following morning receiving water. The trick is to have the stealing of water occur when no one else is around, so that no one is aware what has occurred. In this circumstance, a farmer can get water at the expense of another while a water distribution official makes a few extra kwacha. These individuals benefit, but at the expense of regularly scheduled farmers. This behaviour was described as extremely common at the BVIS in the dry season, but also occurred in the rainy season.

Although farmers described this behaviour as occurring during the night only, upon analyzing the results it seems likely that this behaviour could occur during the day time as well. How this could occur would be for a group of farmers at a tertiary canal to pay for water collectively in order to have it delivered to their tertiary canal. It was observed that only 5-10 farmers at most were present at a tertiary canal when interviews were
conducted, but rough figures indicate that approximately 25-50 farmers are located at each tertiary canal. What this means is that only 20 percent of farmers from a given tertiary canal were present on days when water was scheduled, which seems very low if crops are dry and need water. It is unknown what the price for purchasing water is for an entire tertiary canal, or why only those farmers were present at the tertiary canal on the scheduled date. Ultimately, multiple farmers stated that corrupt behaviour at least occurs at night time and what this creates is a situation where only those individuals fortunate enough to have extra funds can purchase water at times of need. This behaviour compounds with status and power creating conditions that necessitates farmers stealing which is the next circumstance to be described.

Theft

Whereas status and bribery involve water distribution with the assistance of water distribution officials, theft occurs entirely without the permission of water distribution officials. In this circumstance all schedules and management are neglected and farmers do what they can in order to procure the water they need. It needs to be stated that this circumstance is stealing, but from a farmer’s perspective it can be understood and sympathized with. Farmers grow crops in order to earn a livelihood, and when crops are dying they need to be watered. When corruption is high, what other choice do farmers have but to steal water back from those with status or those bribing water distribution officials? This behaviour was described by farmers as occurring at night when there was less monitoring at the scheme. Once those in position had left for the day, farmers would stop the flow of water to those canals and re-direct water to their canals.
Alternatively, farmers would dig channels into a plot with water and direct water out of that field. Farmers are restricted to directing water by gravity, but water was described as being moved across tertiary canals into the fields of another tertiary canal, across drainage canals, and any other direction it could be moved in order to get water to dry crops. All farmers stated that this form of water management was individual behaviour but it seems logical to assume that potentially a group of disadvantaged farmers would work together to direct water to their crops. Farmers may also need to work collectively as this form of water management is time sensitive as it was described as only occurring at night, which only allows for a few hours for these processes to occur.

By the end of the dry season farmers were observed stealing water during the day time. So theft was observed to escalate as the dry season progressed and water supply decreased. On one occasion, an interview started with farmers who stated that they were receiving water as scheduled, but 5-10 minutes into the interview all of a sudden the water stopped flowing to their tertiary canal. The farmers explained that someone had just stolen their water, but there was no way of identifying if the farmers being interviewed were scheduled or paid for water or those farmers who stopped the flow of water to the farmers being interviewed were scheduled or paid for water. All that can be stated is that water flowed to one canal and then 10 minutes later flowed to another canal. At the end of the day, someone stole water that wasn’t supposed to and demand exceeding supply is the reason. The reason for the deterioration in water management is posited to arise because of current governance system conditions and these are discussed next.
6.1.2 Sensitivity

It is posited that the reason water management deteriorates is due to the governance system of the BVIS. In order to assess the governance system of the BVIS, eight design principles for resilient institutions for the management of common pool resources are used as evaluative criteria. These design principles were developed by Elinor Ostrom (1990) and a recent study by Cox et al. (2010) which examined 91 studies to evaluate these principles concluded that they are well supported empirically for analyzing the robustness of self-governing common pool resource systems. Please refer to Table 14 - Design Principles (Peterson, 2011; Cox et al. (2010) for a description of the eight design principles including definitions. These design conditions allow for a baseline condition (current sensitivity) of the governance system to be established which then can be used to assess the vulnerabilities of the irrigation scheme to extreme hydrological conditions.
<table>
<thead>
<tr>
<th>Description</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Boundaries</td>
<td>Presence of well-defined boundaries around a community of users and boundaries around the resource system this community uses.</td>
</tr>
<tr>
<td>2 Balanced Rules</td>
<td>Both appropriation and provision rules conform in some way to local conditions and congruence exists between appropriation and provision rules.</td>
</tr>
<tr>
<td>3 Collective-choice</td>
<td>Most individuals affected by the operational rules can participate in modifying the operational rules.</td>
</tr>
<tr>
<td>4 Monitoring</td>
<td>Monitors who are accountable to the users monitor the appropriation and provision levels of the users and the condition of the resource.</td>
</tr>
<tr>
<td>5 Graduated sanctions</td>
<td>Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both.</td>
</tr>
<tr>
<td>6 Conflict-resolution</td>
<td>Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.</td>
</tr>
<tr>
<td>7 Recognition of rights</td>
<td>The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.</td>
</tr>
<tr>
<td>8 Nested enterprises</td>
<td>Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.</td>
</tr>
</tbody>
</table>

Table 14 - Design Principles (Peterson, 2011; Cox et al. (2010))

6.1.2.1 Clearly Defined Boundaries

The first half of this design principle states the need for well-defined boundaries around the users who may use the resources of the BVIS. In theory, the cooperative’s constitution states that only farmers who stay within the area that the cooperative represents are allowed to become farmers at the cooperative. Cooperative staff also
stated that a signed letter from one of the village headman in the surrounding area is needed for farmers to become members of the cooperative. However, in practice there are not clearly defined boundaries for users at the BVIS. Perhaps 90-100 people rent land at the BVIS at any given time. Local politicians and extension staff also have plots at the BVIS. Additionally, in a discussion with cooperative staff it was noted that some farmers changed their names and procured multiple plots at the irrigation scheme. Although the theoretical limit on the number of farmers at the BVIS is 2067 farmers (official number of farmers in the BVIS), in practice more farmers than this farm at the BVIS during both seasons.

The second half of this design principle states the need for well-defined boundaries around the resource system. There are clearly defined boundaries (i.e. what is inside versus what is not) around the resource system of the BVIS, but these boundaries aren’t enough to prevent users external to the resource system from using water. It was both observed and stated by numerous farmers that during the rainy season numerous farmers outside the scheme tunnel holes into the drainage canals in order to direct water out of the scheme. Additionally, it is possible to capture water that flows out the end of the scheme as there is perhaps one kilometre of land between the canal and Lake Malawi. Theoretically this land in addition to land at the end of the other branch canals could be used by farmers outside the scheme in the rainy season. These gaps highlight that there are clearly defined boundaries but not well-protected boundaries to users outside the BVIS. Additionally, several small-scale schemes (SSS) have been established by the Ministry of Agriculture and Food Security (MAFS) upstream of the BVIS. Every farmer described these SSS as abstracting most of the
water in the Namikokwe River causing water supply issues at the BVIS. Water supply as the BVIS was described as decreasing dramatically due to these SSS. The BVIS has water rights to the water in the Namikokwe River, but practically there are not enforced especially when the government itself is establishing the SSS. These conditions translate into lack of effective boundaries around the resource system.

6.1.2.2 Proportional Equivalence Between Benefits and Costs

The first half of this design principle states that appropriation and provision rules are congruent with local conditions. Historically all land at the BVIS was customary meaning that local leaders were responsible for regulating appropriation and provision in their respective areas. A study completed by Chidanti-Mulunga (2009, p.323) states “Previously, local farmers had been growing rice in rainy season by trapping flood water. Using residual moisture in dry season, they grew upland crops with less water requirement than rice. The whole set-up was farmer-managed, without any intervention from the government. This system had been going on for many years. The government decided to upgrade the existing canal network in the year 2000 with donor funding.” Additionally, Chidanti-Mulunga (2009, p.325) states that “the original scheme was almost twice the current 800 hectares.” Finally, Chidanti-Mulunga (2009, p.327) concludes from his study that comprised interviews of 1928 registered farmers at the cooperative that

“it is clear from the findings that investment in unwanted infrastructure interferes with existing social and cultural practices, thereby reducing land productivity. Government interference by constructing new irrigation structures at Bwanje Valley
Irrigation Scheme brought mixed feelings among the local farmers who originally had their own setup on how to run the scheme. What was thought to be an improvement of irrigation structures became a weapon for destruction of the scheme. Further, the introduction of government personnel to manage the activities of the scheme worsened the situation. In the end, the scheme is less productive now than it was before the so-called upgrading of structures.”

The second half of this design principle states that benefits received are proportional with costs. From 2010 onward, all farmers are required to purchase a share for 1500K, a water fee of 500K in the dry season and an annual fee of 200K. In addition to the payment of fees, maintenance of secondary and tertiary is required of all farmers at the BVIS. Whereas maintenance of the tertiary canals is required on an at least weekly basis if not more during the rainy season, maintenance of the secondary canals is required on an approximately bi-weekly basis if not more during the rainy season. Extensive canal clean ups are scheduled to occur at the beginning of both seasons. The cost to farmers of fees and maintenance is not proportional to the amount of water received for most farmers. Although those farmers (legal or not) with position or those who bribe are capable of receiving water as needed, most farmers do not receive the water they require. Numerous farmers rely on drainage water in the rainy season to irrigate their fields as water doesn’t make it to the end of tertiary canals, but farmers stated they received 90-100 percent of the water they expected. Alternatively, in the dry season farmers stated that they received 30-40 percent of the water they were expecting but it wasn’t delivered on a scheduled basis as expected. Benefits are not proportional to costs in the dry season even with the payment of the water fee.
specifically for the dry season. Overall, in the rainy season benefits may be construed as equalling costs under normal operating conditions, but this is due to the rains and drainage water supplementing irrigation water.

6.1.2.3 Collective-Choice Arrangements

This design principle states that farmers can modify operational rules. All cooperatives are “business organizations that are owned and operated by a group of individuals for their mutual benefit” (O’Sullivan and Sheffrin, 2003, p.202). Theoretically as all farmers purchase shares in the cooperative, they are owners of the cooperative capable of receiving dividends if the cooperative turns a profit. However, the current BVIS cooperative isn’t financially solvent and will remain so for the foreseeable future, which necessitates the involvement of the MAFS in partially managing their affairs. All farmers have the right to vote and be elected to any positions within the cooperative and these elections are held routinely every 3 years. Farmers not elected to the executive council are supposed to have all the rights of the cooperative at annual general meetings. However, it was communicated that no general meetings had taken place for the past two years. Therefore, farmers theoretically only have the opportunity to participate in decision-making processes if elected to the executive of the cooperative. Additionally, due to the insolvency of the cooperative, the extension officers have partial decision-making power which limits the ability of farmers to make decisions by themselves for themselves.
6.1.2.4 Monitoring

The first half of this design principle states that monitors who are accountable to the users monitor the appropriation and provision level of users. Water guards monitor water distribution in the rainy season while water management sub-committee members monitor water distribution in the dry season. Water guards are staff of the cooperative, but it is unknown how the performance of these individuals is evaluated. Water management sub-committee members are accountable to farmers in the elections held every three years, but not during their three year term. Both of these roles are technically accountable to the farmers at the BVIS but in practice are not. Indeed, it is these roles that facilitate corruption at the BVIS. Further, it was communicated that water distribution officials are only the first level of corruption at the irrigation scheme because corruption runs straight to the top of the BVIS. Essentially, the monitors of the monitors condone corrupt behaviour and there exists no provisions for farmers to sanction these officials – remove from office – until the next cooperative elections occur.

The second half of this design principle states that monitors who are accountable to the users also monitor the condition of the resource. Interviews revealed that no direct monitoring of the Namikokwe River was completed at the BVIS, but indirectly most farmers were aware of the up-and-down pattern of the river across seasons as described in the water supply characteristics section of the results chapter. Real monitoring of the conditions of the resource entails water levels being recorded and tracked so that hydrological patterns can be used for planning purposes. It is possible that water levels are kept by the cooperative or the extension officers, but were just not provided during the research. Historically two Government of Malawi gauges were
located on the Namikokwe River and records from these gauges were used in the
design of the scheme, but it is unknown if these gauges are still operational.
Unfortunately, no direct monitoring of the Namikokwe River was found to occur at the
BVIS.

6.1.2.5 Graduated Sanctions

This design principle states that appropriators are likely to be assessed graduated
sanctions. It was communicated by water distribution officials that warnings were given
before fines related to stealing water and non-performance of maintenance. Water
distribution officials stated that they gave warnings to farmers because they
sympathized with them as opposed to there being a formal system of warnings prior to
fines being levied. One water distribution official stated that they gave three warnings
prior to fining a farmer for not following cooperative rules, but no explicit system used by
all water distribution officials was revealed during the research. Discussions with
farmers revealed that water fines were generally 200-500K, but no precise figures could
be determined during the research. At the BVIS an informal system of graduated
sanctions (i.e. warnings before fines) is used to incentivise the actions of farmers.

6.1.2.6 Conflict Resolution Mechanisms

This design principle states that farmers and their officials have rapid access to
low-cost local arenas to resolve conflicts among farmers or between farmers and
officials. It was highlighted by all farmers that they quarrel over water. Indeed, farmers
punch, kick, and cut with knives in order to get water although no one has been killed. It
was communicated by all farmers that there is more quarrelling in the dry season when there is less water. In terms of conflict resolution, water distribution officials stated that it is their role to resolve conflicts. However, in difficult circumstances these officials may get other water distribution officials to assist them or take really difficult issues to the cooperative executive. Although the executive committee has conflict resolution rights, traditional leaders also assist in conflict resolution. These traditional leaders are respected in their positions and although not accountable are also charged with resolving conflicts. It is unknown what conflict resolution mechanisms exist at the executive committee level or with traditional leaders, but it can be hypothesized that these mechanisms are ineffective as farmers resort to cutting each other with knives, which isn’t an effective way to resolve conflict.

6.1.2.7 Minimal Recognition of Rights to Organize

This design principle states that farmers have the right to devise their own institutions that are not challenged by external governmental authorities. The BVIS was imposed on farmers, but after a period of time farmers were given the choice of forming an association or a cooperative. Farmers decided – although to what level or how – that the cooperative was the best decision for them and the BVIS was turned into a cooperative in 2003. However, as has already been stated above, the cooperative isn’t yet solvent and therefore requires the financial assistance of the Government of Malawi in order to operate. Farmers have the legal right to organize and are actually encouraged by government to organize due to decentralization, but these rights aren’t full management rights. The process to full management rights is dependent on
financial solvency of the cooperative which was described as being at least 10 years away. Farmers can organize, but their level of organization is tempered by financial constraints.

6.1.2.8 Nested Enterprises

The final design principle states that management processes are layered in multiple layers of nested organizations. This nesting can be visualized similarly to the branching of canals within an irrigation scheme. For example, horizontal linkages may be represented as one branch canal organization to another branch canal organization while vertical linkages may be represented as a tertiary canal organization to a branch canal organization. At the BVIS there are two layers in practice, which are the farmers’ clubs (remembering these clubs change between the dry and rainy season) and the cooperative. The purpose of this principle is that each organization in the nested hierarchy has the ability to self-govern but in practice institutional constraints limit this ability to self-govern. Several examples of farmers’ clubs working together exist, but the effectiveness of these organizations is limited by water supply conditions of the BVIS. When water supply is high then collective action can occur, otherwise the positive planning of these organizations may be thwarted. Further, corruption was communicated to run straight to the top of the BVIS, so in practice the autonomy of these farmer clubs is non-existent in the face of changing water supply.
6.1.3 Adaptation

The above discussion presents the baseline institutional conditions or current sensitivities of the BVI. Historical adaptations can now be used to assess how the scheme has responded to stresses encountered under normal operating conditions. Each of the different kinds of adaptations will be presented in order to describe what types of changes the BVIS has been able to implement and where difficulties with adaptations are located.

Historical tactical adaptations include field water management training, land levelling and historical responses to flooding. Field water management is a necessity for every farmer. It was communicated by a very successful farmer at BVIS that field water management is an area that numerous farmers neglect and is actually the root cause of most farmers’ inability to deal with changing hydrological conditions throughout the course of the year. This farmer simplified field water management to creating basins around plots in order to hold the water they are supplied with, but unfortunately most farmers do not internalize the training provided and do not practice this adaptation to a sufficient level. One reason for difficulties with field water management is problems with land levelling. Land levelling was supposed to be completed by farmers as a separate construction activity following the building of the BVIS. However, this work wasn’t entirely completed and necessitated it being a component of the rehabilitation that occurred in 2008. One farmer was interviewed whose land was not level at all, so gaps still exist, but overall farmers didn’t complain about current land levelling but stressed it was an issue in the past. The BVIS was eventually able to adapt with respect to land levelling but still has issues related to field water management. Historical response to
floods gives an indication of how the BVIS responds to extreme hydrological events. Temporarily a wooden canal was constructed to replace the damaged section of M1 until a permanent reconstruction could be completed during the rehabilitation. These tactical adaptations are not simple measures, but some farmers are still not capable of managing water at the field level properly, land levelling was completed almost 10 years after construction, and fixing a damaged canal took until a rehabilitation project in order to be completed. These adaptations highlight that even when tactical changes are required that the BVIS is slow to implement these projects.

Strategic adaptations involve improving the effectiveness of how things are currently done, and several adaptations have been completed including: land reallocation; switching crops; changing the water schedule; command area re-sizing; and modifying cropping calendar. Land reallocation was necessary at the BVIS because some farmers had multiple plots, but weren’t farming them due to their working requirements leaving some land in the BVIS fallow. The land reallocation was completed as part of the soft components program of the rehabilitation program. This allowed all farmers to have the same amount of land in the rainy season. The command area is reduced in the dry season because of lack of water, which is another adaptation to changing water conditions. The BVIS initially started producing rice in both seasons, but lack of water necessitated the switch to a crop that used less water in the dry season. The water schedule was also modified from a 4-day to 3-day schedule because the former resulted in crops not getting water when needed. As described above, the command area decreases in the dry season and this planned change was a part of the original design of the BVIS. Finally, the cropping calendar needs to be shifted, such as
the dry season observed during the research. An infestation of mice destroyed most of the maize crops that were planted earlier in the dry season. A second maize crop had to be planted, which placed a large financial burden on farmers who were forced to purchase a second round of inputs. These adaptations are all system wide, long term, and policies for the entire BVIS. They are reactive to changing conditions, but planned in implementation. These adaptations predominantly occurred during the rehabilitation because the BVIS must wait for external funding agencies to provide the capital in order to complete them.

Finally, transformative adaptations are not common as they drastically change the entire make-up of an organization. There are two large transformative adaptations that have occurred at the BVIS and these are the building of the BVIS itself and the change from a government run irrigation scheme to a cooperative led scheme. These long-term, planned, proactive, and widespread policy initiatives have changed the nature of business at the BVIS. These transformations cannot be implemented without inputs from external agencies of the Government of Malawi.

6.2 Extreme Hydrological Conditions

6.2.1 Floods

6.2.1.1 Exposure

The first extreme hydrological condition that may affect the BVIS is floods. Floods are defined as flow events that overtop existing channels. According to water guards at the BVIS, there are too many instances to count of elevated water levels on the Namikokwe River. However, these events cannot be classified as flood events. Two
actual flood events where flows overtopped the river channel have occurred at the BVIS since its construction and these occurred in 2002 and 2003. Additionally, an extreme high water event struck the scheme in 2009 when river flows reached the underside of the inspection bridge. These events last no longer than a period of a few hours and are described as flash events with rapid onset and subsiding. Longer duration high water events lasting up to a week also occur on an infrequent basis. All high water and flood events occur during the rainy season. All floods have the potential to cause devastating impacts if large enough.

6.2.1.2 Sensitivity

Before describing the governance system sensitivities, the resource system sensitivities will be described. The two areas most directly sensitive to flood impacts are the headworks and the flood dike road which come in direct contact with the river channel. Protection against high water events was a design consideration in their construction. The original headworks were designed for a flood discharge of a 50-year return period while the flood dike road alongside M1BC1/BC2 was designed for a flood discharge of a 25-year return period (NKC, 1997). Additional protection in the form of a dam was considered but no suitable dam sites were located during the completion of the feasibility study on the Namikokwe River upstream of the BVIS. These flood protection measures were unable to protect the BVIS when a flood damaged the headworks and a 60 metre section of the M1 canal in 2002 and 2003. During the rehabilitation, the headworks were elevated and the flood dike road reinforced with gabion baskets in sections in order to protect the scheme. The headworks always
remain in danger of being damaged by flood events as they must be located beside and on the river in order to complete the abstraction process. The rehabilitated headworks were designed for it is assumed a greater flood discharge return period than the 50-year return period of the design. To what level is unknown, but damage would necessitate strengthening. However, water did touch the underside of the inspection bridge bringing it very close to the edge the previous year, so this shows how precarious their current condition is.

While the headworks have been elevated, these measures directly put the flood dike road at greater risk as the headworks now channel any elevated or flood flows downstream and the flood dike road is located directly downstream. Only the first section of M1BC1 and the first section of M1BC2 are located adjacent to the river and these sections are perhaps at most 2-3 kilometres in length. No other sections of the scheme are located adjacent to the river, which reduces the overall exposure potential for the scheme. There is still potential for impacts as historical damage to the dike road shows. This discussion reveals the sensitivities of the resource system, but governance system sensitivities exist as well.

In order to evaluate the governance system, Ostrom’s design conditions are used to predict where sensitivities exist in the event of a flood as compared to normal operating conditions. If the headworks were permanently damaged, the only perceived sensitivity related to the design principle of clearly defined boundaries would be farmers vacating the scheme until it was rebuilt. If no water could be supplied then farmers would no longer expect water deliveries and demand would decrease. This isn’t a positive condition rather a reality of the nature of the headworks being severely

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damaged and no longer able to perform their intended function. As farmers already neglect maintenance tasks, a flood event depressing water supply wouldn’t encourage normal maintenance or rehabilitation to be performed because benefits are further depressed in relation to costs. The greatest sensitivity of the governance system relates to collective-choice arrangements. As discussed, not all farmers are capable of participating in decision-making processes for the cooperative. It is predicted that only those individuals with positions would have direct input in any process due to the fact that annual meetings and lack of communication and coordination are large problems at the BVIS. There are provisions for emergency meetings, but again it appears that only those currently in positions would be able to participate in any capacity with respect to decision-making. However, with the scheme no longer abstracting water and the damage requiring external assistance in order to rehabilitate the headworks, it is hypothesized that the right to directly influence outcomes would be reduced.

The construction of the BVIS and the rehabilitation were largely externally driven programs and it is anticipated that a similar approach would be used in the event of a large flood. The reason for drawing these conclusions is that most farmers stated that they weren’t involved in the design of the scheme to begin with or in the rehabilitation. It is predicted that the nesting of organizations would disappear as external agencies begin to take responsibility for any rehabilitation program. Reduced responsibility of the cooperative is due to the fact that they currently are not capable of managing their own financial affairs due to lack of capital. In a flood event there would be no further need for monitoring or sanctioning as water is no longer supplied to the BVIS. Finally, conflict would increase as farmers no longer get the water they need, but as farmers become
aware that the scheme can no longer provide the input they need, farmers would most likely move elsewhere until the scheme was rehabilitated. The greatest sensitivity of the governance system is the cooperative’s lack of true power and authority due to insufficient funds. A large event would bring in government and external agencies shifting decision-making outside the organization as has been done in the past.

Damage to a section of M1BC1 or M1BC2 reveals several sensitivities that wouldn’t be experienced in the result of a flood damaging the headworks. Reason being that damage to the headworks affects the whole scheme whereas damage to the area of the flood dike road only affects a small section of the overall scheme. Sensitivity is also dependent on time as an event at the beginning of the rainy season would be different from an event in the middle or later in the rainy season. An event in the middle or end of the rainy season would unfortunately cause irreparable damage to the farmers affected as there isn’t sufficient time to grow another crop somewhere else in the scheme or the surrounding area even if land was available. In the case of a flood occurring at the beginning of the rainy season, there is time to respond but perceived sensitivities would limit opportunity for adaptation. Currently, there are farmers who aren’t members of the cooperative that farm the BVIS in both seasons, so theoretically there is space within the BVIS to shift farmers to other locations. There currently is no equivalence between benefits and costs so it wouldn’t be illogical to assume that extra work would not be performed by farmers who already are busy in the rainy season with any action in the damaged areas. Farmers elect officials to the cooperative committees, but after these elections farmer input is reduced as farmers stated they are infrequently
consulted on the affairs of the scheme. Infrequent consultation would predict that farmer participation in any scheme response would be limited as well.

While shifting farmers to another section would keep the same number of farmers in the scheme requiring water, the scheduling and monitoring of this shift seems beyond the abilities of the cooperative as it is currently structured. Conflict at branch canals which would now have a greater number of farmers would go up as discussed in the water circumstances. If farmers were to move to other sections of the BVIS then monitoring and sanctioning would have to adapt and these processes already prove insufficient to deal with current problems. Conflict would be increased and current mechanisms are again insufficient to deal with problems that arise during normal operating conditions. Therefore, expecting improved performance in this category doesn’t appear likely putting this process at risk. Farmers have the right to organize but current farmers’ clubs don’t appear to carry much actual responsibility when it comes to water management as responsibility is held at the collective-choice level of the scheme. Theoretically, the nesting of responsibility is supposed to improve governance and management, but currently this nesting proves ineffective at managing problems because problems are the result of actions at a higher level. Ultimately, the sensitivities of the BVIS to flood events are high with limited adaptation potential.

6.2.1.3 Adaptation

There exists multiple resource system and governance system sensitivities that adaptation would need to reduce in the event of a large flood damaging the headworks, the flood dike road, or both. Potential resource system adaptations revolve around
protecting the water structures of the BVIS. Water guards are stationed at the headworks - day and night - to monitor water levels and to close the headworks when water levels are perceived to potentially have a negative impact on the scheme. This is the only monitoring and reactive system that was observed in terms of a response to floods. However, in the event of a large flood instantaneous monitoring can only warn the scheme minutes or hours in advance not allowing the BVIS any time to practically respond. The BVIS relies on the design ratings of these systems as no other options exist for mitigating the damage of floods. Were the headworks or the flood dike road to be damaged then limited potential for adaptation exists in the current growing season. Damage to the headworks would require another round of rehabilitation depending on the severity of the damage, which if the headworks were disabled would cause large-scale damage to all farmers within the scheme. As the previous rehabilitation took years in order to be implemented, the potential for any realistic adaptation during the rainy season affected is negligible. A large-scale flood would force farmers to rely on the rains again and with the number of farmers in the scheme this would result in a large-scale governance problem.

Were a section of M1 to be damaged then potential exists for the scheme to adapt to the changed conditions, but not for farmers affected. As discussed above, a section of M1 was temporarily reconstructed after the floods in 2002 and 2003, which allowed for the scheme to continue operating. Floods are a rapid onset and subsiding event that with current resource system sensitivities only allow for reactive responses to address impacts after-the-fact. The response to damage of the flood dike road would be the construction of a more elevated flood dike road to protect the scheme at some point in
the future. However, the construction of such a dike would be beyond the scope of the BVIS directly following a flood event. There are responses that could be initiated for farmers affected by a flood event along M1, but these are governance issues that will be discussed in the next paragraph. The direct impacts of floodwaters on farmers with plots adjacent to the river would be their fields would be flooded. Floodwaters would eventually subside as these areas are connected to the overall drainage system, but the length of time for this to transpire would be in the days or weeks. Any impacts to the headworks or the flood dike road would require reactive responses. As already discussed in the adaptations section under normal operating conditions, the majority of responses to hazard events occur after-the-fact, are planned actions by external agencies, and long-term changes due to the low frequency of opportunities for external agency assistance. The nature of current adaptations just wouldn't allow the BVIS to adapt properly due to the nature of how large-scale adaptations currently occur in the short-term, but long-term adaptation is possible but not assured.

With respect to governance, temporary changes until rehabilitation occurs are possible as the scheme has survived floods in the past, but the level of adaptation without external assistance appears to be low. No governance options exist if the headworks are severely damaged as this would result in no water being available to the irrigation scheme. With no water, there is no need for governance of the scheme. Any governance system adaptations were a portion of the farmers to be affected by the floods would obviously be a reactive response to the flood event. One potential scenario involves moving farmers to another area of the BVIS while their former areas are rehabilitated, but this depends on when a flood event occurs. A flood at the beginning of
the rainy season potentially allows time for a response with the current growing season. However, similarly to resource system adaptations such a response appears unlikely in the short-term. Most adaptations to the governance system were implemented on the recommendation of external agencies and were implemented as part of the rehabilitation program. Current sensitivities in the governance system appear to limit the potential for any short-term solution. A large-scale flood event appears beyond the capacity of the BVIS to respond. That is not to say that something couldn’t be done, rather that implementation appears unlikely due to current deficiencies. This condition makes the BVIS extremely vulnerable to flood events.

6.2.2 **Droughts**

6.2.2.1 **Exposure**

All forms of drought occur on a yearly basis at the BVIS, but they occur for different reasons. Hydrological and meteorological droughts occur because the bulk of the rains in Malawi come during the rainy season following the normal climatic pattern. All the characteristics of these drought events can be easily described. The frequency is yearly, while the duration and timing are seasonal. Rate of change is as simple as when the rains start and stop in the rainy season. Magnitude for these two categories is absolute for meteorological drought as the rains stop, while hydrological drought would be proportional to the observed drop in water levels in the Namikokwe River. Both of these forms of drought occur solely because of climate. Both agricultural and socio-economic drought occurs within the BVIS not only because of climate but due to lack of effective water distribution. All the characteristics of these drought events are similar to
meteorological and hydrological drought except for magnitude. Magnitude is a bit more complicated because meteorological and hydrological droughts refer to events that affect the whole system equally whereas agricultural and socio-economic droughts impact farmers differently depending on location within the scheme and other factors. However, both of these forms of drought occur yearly at the BVIS it is just the proportion of those affected that may change. At the end of the day, all forms of drought occur on a yearly basis at the BVIS.

6.2.2.2 Sensitivity

Knowing that drought affects the BVIS yearly, it is important to understand the impacts of these drought events. The physical effects of drought are simple to understand and observe. When water isn’t supplied to a crop it gradually wilts and ultimately dies unless water is supplied. Unlike flood events, there are no other observable physical impacts such as the headworks being damaged. Drought plays out differently than floods resulting in predominantly governance system impacts alone. How drought affects the BVIS is that the effectiveness of water management decreases with decreasing water supply as the discussed water circumstances highlight.

Decreasing water supply leads to individuals with status and power getting water along with bribery and theft, which arise due to governance system deficiencies. The current institutional structure of the BVIS proves insufficient in its response to these events. A large-scale drought event reducing all flow of water into the BVIS would collapse the scheme during the season affected. With no water there are no adaptations that could occur to somehow share water because no water exists. This condition is occurring with
the elevated abstraction of water by the SSS upstream from the BVIS, but this is not the focus of this thesis.

In using Ostrom’s design principles, there are insufficient boundaries at the BVIS preventing non-members from farming. This adds stress to the system making any response that much more difficult to achieve. Decreasing supply leads to a lower receipt of benefits as compared to cost, which reduces the ability for collective action related to water management and maintenance. Collective-choice is already the largest sensitivity and decreased supply of water would further exacerbate the situation. Less water means more reliance on negative behaviours, which are facilitated by those in power at the BVIS. It is inconceivable that water management would improve in any fashion were a large-scale drought to occur. Monitoring and sanctioning processes would become even more difficult to properly achieve as those individuals responsible for implementing these processes are those responsible for corruption. Conflict would increase and there appear already insufficient mechanisms for dealing with these situations. The nesting of enterprises and the rights to organize are where serious potential problems could exist. What prevents farmers from abandoning the scheme, or even worse revolting against those in charge? No revolt was ever mentioned in any interviews and did not appear to be a concern, but if things became really bad what prevents such a situation from arising? The current governance system facilitates inefficient water distribution due to lack of available water, and were a very serious drought event to occur then it appears that some form of strike or other response is possible although again never discussed by any farmer. Most likely farmers would abandon the scheme and try to earn a livelihood in another fashion. An extremely damaging drought initially leads to ineffective
water distribution system, which leads to crop losses followed potentially by compromised livelihoods. The purpose of irrigation is to supplement rainfall and when there is no water it becomes a serious problem. Every irrigation system is sensitive to drought, but there are minimal adaptations that the BVIS can implement to overcome these challenges due to governance system vulnerabilities.

6.2.2.3 Adaptation

Most, if not all of the adaptations that have been completed at the BVIS are to deal with drought or water scarcity. Seven of the eleven adaptations relate to drought or water scarcity and they include: field water management; land levelling; switching crops; water schedule; command area sizing; cropping calendar; and BVIS construction. The BVIS itself is a technology to better deal with available water although it does increase demand. The remaining adaptations specifically adapt the BVIS to drought conditions. Field water management works with the water available at the field level in order to use it as productively as possible. Land levelling similar to field water management strives to make it easier to use water supplied to the fields. Switching crops from rice to maize, command area sizing, and cropping calendar are all responses to water scarcity. Most changes at the BVIS are donor implemented and the purpose of these changes is to more productively use the water resources available to the BVIS. These adaptations however have only minimally reduced the vulnerability of the BVIS to drought events.

The sensitivities of the BVIS were described above as relating predominantly to the governance system. Further modifying schedules, improved water management, reducing command area, etc… all require an effective governance system to implement
and current capacity to deal with decreased water supply doesn’t appear to exist. From an examination of the historical adaptations, all adaptations predominantly occurred during the construction and the rehabilitation of the BVIS. For example, a large number of farmers had several plots in the scheme, but it took a land reallocation coordinated by an external consultant in order to remedy this situation. Land levelling was supposed to be completed during the construction by the Government of Malawi, but it was completed following construction and still remains incomplete after the rehabilitation. These adaptations reveal that any governance system adaptation requires external assistance in order to even be partially completed. This is not to say that the BVIS doesn’t want to improve its processes, but what appears is that it is incapable of completing them without outside intervention. Most adaptations to the BVIS are externally driven, scheme-wide, long-term focus, and reactive changes to events that have already occurred. A large-scale drought event requires a timely response in order to mitigate its effects, but the current process by which adaptation occurs wouldn’t be able to respond adequately during a season of extreme drought. What would most likely occur is that a large proportion of farmers would lose their crops, and farmers would pray for better rains the following season. Numerous farmers spoken with at the BVIS stated they had no intention of planting maize in the dry season the following year because of water problems. The potential rewards just didn’t outweigh the risks. The reliance of the BVIS on water makes it more than extremely vulnerable to drought and current capacities reveal limited potential to avert catastrophe.
7 Conclusion

7.1 Vulnerability

This chapter draws conclusions of the vulnerability of the BVIS under normal and extreme hydrological operating conditions (Research Objective #4). The BVIS is vulnerable in all conditions – normal, drought, and flood – because it utilizes a common pool resource that is part of a larger ecosystem. The related ecosystem determines the amount of water available for irrigation and as currently constructed there is nothing that the BVIS can do to change this fact. There is no dam that would enable the storage of water on a temporary basis to reduce vulnerabilities to changing water conditions. The following conclusions are drawn for each of the actual and predicted scenarios of the BVIS related to available water supply.

7.1.1 Normal Operating Conditions

Under current operating conditions, the BVIS is more vulnerable in the dry season than it is the rainy season. Conclusions for each of these seasons will be provided in turn. Starting with the less vulnerable rainy season, the availability of more water creates a condition where the BVIS can adequately respond to changing hydrological conditions. All farmers stated that more water is available in the rainy season and since less farmers rely on irrigation water it creates is a water surplus for those farmers that do rely on irrigation water. When water supply is elevated there is an increased potential for collective action, which translates into water distribution circumstances that are more equitable to all farmers on a tertiary canal. Negative behaviour still exists, but potential conflict is reduced because problems can be averaged out across all the remaining
farmers having less of an effect. If it rains in the rainy season and the scheme is capable of abstracting water from the Namikokwe River then it can successfully operate on a year-to-year basis.

The BVIS is sensitive because its governance system fails to meet the design criteria for robust institutions. The BVIS only moderately satisfies the graduated sanctioning and rights to organize design criteria. These are classified as moderately satisfying because graduated sanctioning occurs on a limited basis, and farmers have the right to organize but applying those rights isn’t as effective as farmers would like or as this principle intends. With 6 out of 8 design conditions given a fail rating, and the remaining two given a moderately successful rating, it cannot be stated that the BVIS is a robust institution. What this leads to is the BVIS being extremely sensitive to changing hydrological conditions. Any moderate change in hydrological conditions (i.e. constant heavy rainfall) could descend the system into a negative condition. The governance system performs well if it can operate under status quo conditions all of the time, but its capacity to adapt to any stressor is low. This is due to the nature of the current adaptive processes used at the BVIS which only allow for reactive and planned adaptations on a small-scale basis unless externally assisted. The good in this situation is that the rainy season is when most of the farmers earn their livelihoods for the year and every farmer is extremely thankful when the rains come as it translates into livelihoods and success for the overall scheme.

Conditions in the dry season are when problems begin to happen. Decreased water availability translates into less effective water management where status and bribery allow fortunate individuals to receive water with theft also occurring. The
reasons for this behaviour are that the resource the BVIS is designed to supply isn’t being supplied, and farmers are left with no alternative, but to procure water through other means. The current governance system of the BVIS cannot adequately respond and in most cases facilitates negative behaviour which is the reason why the scheme’s water management system deteriorates so badly. The same design conditions for robust institutions apply equally, if not worse, in the dry season. For example, benefits become even less proportional with costs which produce the negative water management circumstances. The BVIS already has limited capacity to adapt in the rainy season, and less water means that even fewer adaptations exist to improve things in the middle of the dry season. Farmers at the BVIS discussed abandoning the scheme in the worst part of the dry season indicating their lack of faith in any real change to be implemented to assist them with their crops. With no water there really is no change that could occur. This system is so entirely dependent upon the rains and when there is no water it means potential disaster. There are no scheme-wide adaptations that can be implemented in the dry season to improve conditions for all farmers. When no adaptations can occur, this means the scheme is extremely vulnerable. As compared to the rainy season, the dry season makes for precarious operating conditions.

7.1.2 Extreme Hydrological Conditions

7.1.2.1 Floods

Floods can only damage the headworks and the flood dike road in the rainy season. Depending on which element is affected, different outcomes will occur. Were the headworks to become irreparably damaged then the scheme would shut down.
Were a section of the flood dike road be damaged then perhaps only a small segment of the scheme would be affected. Water management operates at its peak effectiveness during the rainy season, which provides for some flexibility if only a section of the scheme is affected. Depending on when a flood struck the BVIS would dictate whether the BVIS was capable of responding. A flood at the beginning of the rainy season would potentially give time to react whereas a flood in the middle or later in the season wouldn’t allow any time to react. The reason for this statement is at the beginning of the season farmers could potentially start over in another area of the scheme. Procedures are in place to mitigate the effects of floods as much is possible through closing the headworks and monitoring, but these processes only provide time to protect structures not to deal with the effects of a flood. These structural mitigations do not assist in the adaptation process. Local conditions and an increased frequency of flood events due to potential climate change make the scheme vulnerable to floods, but there is no alternative in an irrigation scheme. Structural adaptations aren’t possible on a short enough time frame to reduce the vulnerability of the BVIS and institutional adaptations cannot be implemented in a short enough time frame to be successful at minimizing the effects on the system. External assistance is needed for adaptations that would assist the BVIS in responding to floods and that assistance wouldn’t be provided when needed in the short term.

7.1.2.2 Droughts

Droughts have the potential to have the most devastating impact on the BVIS. These events strike the BVIS every year and every year have negative effects.
Vulnerability is the ability of the BVIS to respond to hazards, and the BVIS cannot respond to droughts adequately. Drought shifts water management from an effective to an ineffective state, and adaptations to improve this situation cannot be implemented by the cooperative itself. The BVIS as an organization will survive a season of drought due to demand for farming spots. However, the livelihoods of more vulnerable farmers such as those that cannot purchase water are in serious jeopardy. The institutional vulnerabilities described above illustrate that planned adaptations have a poor chance of success based off of the historical implementation record of the BVIS. Only external funders can provide the means to implement long term and widespread change, but even then there are too numerous vulnerabilities that hamper their successful continued function. Efforts may work while donors are present, but continued implementation is a sore spot due to insolvency of the BVIS. Current vulnerabilities make adaptations difficult to implement and donors can only help so much, therefore droughts have the ability to destroy the BVIS with no options to avert this tragedy for the season affected. The organization will recover the next season, but the farmers may not, which is who the BVIS is trying to help.

7.1.3 Overall Vulnerability

All adaptations of the BVIS to changing hydrological conditions and extreme hydrological conditions are reactive in nature because they cannot be implemented without donor assistance. This scheme doesn’t have the capacity to adapt because its governance system isn’t robust enough. While floods and droughts have different effects on the system, they both suffer from the same inability to adapt to these
conditions. Anything that makes water delivery to the scheme decrease means water management deteriorates. Irrigation is only possible when water is available, and if it is not then everything suffers. Rapid onset climate change producing a greater frequency of floods and droughts will cause serious damage to the BVIS. Slow onset climate change will provide an opportunity for adaptation as it allows external assistance to facilitate adaptation.

7.2 Recommendations for System Performance

The overall goal of this thesis was to understand how an individual irrigation scheme was vulnerable to extreme hydrological conditions. During research design it was assumed that water management processes would change in response to changing conditions, but that overall the irrigation scheme could adapt. What this research has revealed is that social-ecological systems are completely and totally dependent upon inputs from the external environment (i.e. related ecosystems) for their sustainability. With no water then these schemes cannot function. This fact is simple to understand and was understood prior to research but not truly appreciated. This research has most definitely revealed how important management of our water is to the sustainability of the organizations that depend upon this resource. Malawi, like everywhere will continue to demand more and more water from its environment as populations grow. This means that adaptation to population growth and the effects of climate change is important if food security and jobs are to be continually secured. This section will provide several recommendations so that the BVIS may adequately respond
to climate change. These recommendations relate directly to Ostrom’s design conditions.

7.2.1 Monitoring

We cannot manage what we don’t keep track of. Mostly everyone balances their check books on a frequent basis so that decisions can be made with respect to how funds are spent. The same principle applies to water, and it is needed at the BVIS. No water records were kept at the BVIS and with no water records there is no accountability for the amount of water delivered to an individual farmer’s plot. No monitoring at the BVIS seemed an advantageous condition for those with power and authority. This created the situation where no farmer could walk to the office and say water levels are this much in the river, and I only received this much water yesterday, why? Not only does tracking water levels on a yearly basis enable accountability, it also enables planning such as with a check book. Undoubtedly, having a record of available water will pose problems, but they are good problems. Were supply always to exceed demand then monitoring isn’t as important, but current conditions on the Namikokwe River produces periods where water is scarce. When something is scarce it has value. When something has value it should be monitored.

7.2.2 Collective-Choice Arrangements

As currently structured the collective-choice level of the BVIS doesn’t appear accountable to its operational level. Structures are in place for accountability but in practice they do not function. Farmers expect water, but understand that in times of
water scarcity that they will not receive the water they need because their governance system functions as an inefficient water distribution system. Granted water supply is reduced in the rainy season, but several farmers stated that the water scheduled posted during the research was only posted because of the research. Farmers stated that there is no schedule at the BVIS because water management doesn’t operate in a scheduled way. This is a problem, but those with the power to do something about it profit from the system as it is structured, so there is no incentive to change the structure. The most important incentive needed is accountability. Annual meetings need to be held and extension officers and cooperative staff need to be accountable to the farmers’ that pay for the system to operate in the first place. The local context is poorly understood at the present time, so how such a transformation would take place is unknown. However, instituting an accountability process seems like a good first place to start to improve operations.

7.2.3 Congruence between appropriation and provision rules

From the management framework used as part of this study, control processes appear to be the most important part of an organization after is has been established. Goals and structures are established during design, but ensuring that the system operates towards its desired goals as opposed to other goals requires rules. Water distribution officials and farmers continually stated that tertiary canals are required to be filled from front to back, but multiple observations revealed that this doesn’t always occur. Annual general meetings are supposed to be held every year, but those meetings haven’t occurred in two years. The fine for stealing water is a few hundred
kwacha, yet water distribution officials allow for corruption to occur without sanctions. Well-defined rules tie in with accountability, but in this recommendation are intended to represent on-the-ground controlling of actions so that the system functions as intended. Both operational and collective-choice rules that regulate how water is distributed are needed, so that an actual schedule can be established that is followed. Increased fees could perhaps be appropriate, but fines based on rules that restrict behaviour are most likely more appropriate. Rules created by farmers for farmers that balance benefits with costs should improve water management.

7.2.4 Well-Defined Boundaries

When farmers were asked about reducing the number of farmers in the BVIS, dumbfounded expressions quickly became apparent on their faces. Why would a researcher ask such a silly question? Supply-side management is one means to deal with water problems, but demand-side management is also an option. The quickest way but not necessarily the easiest way to do this is to eliminate extension officers and local politicians having plots in the scheme. These officials take the best plots for themselves and take water out of the system that could go to farmers that are paying for water to begin with. However, it was perceived that there were just too many farmers for too little water. Farmers relying on drainage water in the rainy season corroborate this opinion for the season not observed. Too many farmers vying for too few resources makes all suffer, some more than others. How to accomplish reducing farmers in the BVIS would be extremely difficult because how are these choices made? Also, the BVIS was created to increase employment, so this goes against system goals. Perhaps only
decreasing the number of farmers in the dry season is the best way to accomplish this task, but something needs to be done to reduce demand. Improved technology isn’t possible due to cost restrictions, therefore reducing demand can literally only be accomplished through reduction in farmers.

7.3 Implications for Adaptation Processes

Adaptation processes are difficult processes because they require tactical, strategic, and transformative change to occur in organizations that may be resistant to those changes. Using the questions how does adaptation occur and what are the limits of adaptation, the following implications for adaptations processes are presented.

7.3.1 How does adaptation occur?

Both timing and intent are important characteristics for adaptation processes. Whereas timing refers to whether an adaptation is proactive or reactive, intent refers to an adaptation being known in advance (i.e. planned) or muddled through (i.e. spontaneous). All adaptation processes should be proactive and planned, but things don’t always work out that way. With respect to intent, planned adaptations based off assessments conducted in advance of stressful conditions that lay out potential options and their consequences would allow for more targeted and appropriate responses. Studies such as this thesis provide information to planners so that planned adaptations may occur. Not only do planned adaptations enable more targeted responses, but they allow for proactive adaptations to occur. Proactive adaptations are what climate change studies have been preaching for decades and those studies may not be right in their
recommendations, but are right with respect to the nature of how adaptations should be carried out. Proactive as opposed to reactive change averts crisis before crisis becomes crisis. However, in the developing world for these changes to occur there needs to be financial assistance otherwise adaptation cannot occur. Both governance and resource system adaptations require funds that aren’t available to small organization such as the BVIS. Funding is the key constraint on adaptation processes at the BVIS, a problem which it cannot resolve on its own at least in the foreseeable future, if ever.

Planned and proactive adaptation processes also need to be coupled to local conditions. Processes proposed externally that do not respect cultural norms are more prone to failure than those that do respect cultural norms. The BVIS was a transformative adaptation that permanently modified how agriculture is practiced in the Bwanje valley and the system is still dealing with the repercussions. Local norms are minimally understood from the research completed for this thesis because understanding of water management and vulnerabilities are based on a Western mindset researching a Malawian system. More time is needed in the field to be able to express confidently how processes occur at the BVIS, but this understanding is required for adaptation processes as well. Status and power being used to receive water isn’t frowned upon, but what cultural norms compel a farmer to monitor the person receiving water in this fashion? There are reasons for this behaviour and any adaptation process should be more aware of this underlying cultural context.
7.3.2 What are the limits to adaptation?

Scope of any adaptive action is extremely important, and specifically for projects in the developing world it is hypothesized to be even more important. While results from this thesis cannot be generalized to other irrigation schemes, results show that for the BVIS it is limited in the scope of adaptations it can implement. Again, donor funding is the issue in that it limits when adaptations can occur. These limits are due to the fact that rehabilitations don’t happen every 6 months rather they happen every 10 years if systems are lucky. This translates into adaptations having to focus on the long-term and for the entire system not specific areas or durations. However, adaptation is a process and the first attempt may not be determined to be appropriate after 6 months of implementation, but it is forced to be right as there is no opportunity for another alternative to be tried. A more adaptive management approach to adaptation processes would allow more interventions of a smaller scope to be implemented in order to learn from mistakes and make improvements for the future. If adaptations must be large and long in scope, then donors better be sure that they are getting things right the first time, because there won’t be a second time for a long time. Adaptation like development is a process and these are both learning processes. Recognizing these limits will go a long way towards better development interventions.
References


*Proceedings of the National Academy of Sciences of the United States of America (PNAS)*. 100(14): 8074-8079.


Plate 3 – Scouring Sluice Gates

Plate 4 – Scouring Sluice Gates
Plate 7 – Settling Basins

Plate 8 – Gate Structure
Plate 9 – Primary Canal

Plate 10 – Primary and Secondary Canal (Primary Right and Secondary Left)
Plate 11 – Tertiary Canal

Plate 12 – Bifurcation Structure
Plate 13 – Bifurcation Structure

Plate 14 – Turnout Structures
Plate 15 – Field Canal Structures

Plate 16 – Field Canal Structures
Plate 17 – Primary Drain

Plate 18 – Secondary Drain
Plate 19 – Tertiary Drain

Plate 20 – Tertiary Drain