Using the resilience assessment approach to evaluate social-ecological systems at the North-West University (Vaal Campus)

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DECLARATION

I, Irene Muller declare that *Using the resilience assessment approach to evaluate social-ecological systems at the North-West University (Vaal Campus)* is my own work and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

Signature: _____

Date: _____

ACKNOWLEDGEMENTS

In life's journey constant companions make it worthwhile.

I wish to express gratitude to:

Father God, for strength and courage; opportunities according to Your time.

My supervisors, Mr Jan-Albert Wessels and Prof Johann Tempelhoff, thank you for your patience and fruitful contributions when I needed it.

My husband Heine, for your loyal support, encouragement and love.

My sons, Leon and DP, students like myself. What a privilege to be studying at the same time. I hope that we can graduate together.

Mom, for emphasizing the value of education.

All role players on the NWU (Vaal) campus who participated in this research study for valuable and interesting contributions.

My fellow students, for sharing enjoyable and difficult times on Friday nights and Saturday mornings. Alone would have been boring.

"Make things as simple as possible, but not simpler" – Albert Einstein (cited in Gunderson & Holling, 2002:25).

ABSTRACT

This research reports on the use of the resilience assessment approach to evaluate the social-ecological systems (SES) at the NWU (Vaal) for a nine month period from March 2013 to November 2013. The research aims to determine the merits of the use of a resilience assessment approach to determine the resilience of the NWU (Vaal) in respect of social-ecological systems.

Objectives of the research include the identification of disturbing events to environmental resilience, to construct a conceptual social-ecological systems model of the NWU (Vaal) in order to determine thresholds relevant to resilience and to determine if the resilience assessment approach can be applied at the NWU (Vaal).

Data was collected in the form of a literature review, which aided with the construction of a time line for the focal social-ecological system; document reviews, interviews with relevant role players, observation by the researcher and the use of the assessment approach to construct the social-ecological system model.

The research findings include identification of possible disturbances and thresholds relevant to resilience of the social-ecological system of the NWU (Vaal). The construction of a social-ecological system model of the NWU (Vaal) aids with proposals to incorporate a stewardship approach which enhance resilience of the focal social-ecological system.

Key words: resilience, social ecological systems, resilience assessment approach, disturbances, thresholds, stewardship approach

OPSOMMING

Hierdie navorsingstudie rapporteer oor die gebruik van die Veerkragtigheids Assessering Benadering om die sosio-ekologiese sisteem (SES) van die NWU (Vaal) te evalueer vir ‘n nege maande periode van Maart 2013 tot November 2013. Die navorsing poog om die meriete van die gebruik van die Veerkragtigheids Assessering Benadering om veerkragtigheid van die NWU (Vaal) met betrekking tot sosio-ekologiese sisteem te evalueer.

Doelwitte van die navorsing sluit in die identifikasie van gebeure wat veerkragtigheid versteur, die konstruksie van ‘n konseptuele sosio-ekologiese sisteem model vir die NWU (Vaal) ten einde keerpunte relevant vir veerkragtigheid te bepaal en om te bepaal of die veerkragtigheids assessering benadering toegepas kan word op die NWU (Vaal).

Data is ingesamel tydens die literatuur studie, wat bygedra het tot die konstruksie van ‘n tydlyn vir die fokus sisteem; ook is relevante dokumente hersien; onderhoude is gevoer met relevante rolspelers; observasies is gedoen deur die navorser en die assesserings benadering is gevolg om die sosio-ekologiese sisteem model te konstrueer.

Die bevindinge van die navorsing sluit in identifisering van moontlike versteurings en keerpunte relevant tot veerkragtigheid van die sosio-ekologiese sisteem. Die samestelling van die sosio-ekologiese sisteem model van die NWU (Vaal) help met voorstelle rakende die navolging van ‘n verantwoordelike benadering om veerkragtigheid van die fokus sosio-ekologiese sisteem te bevorder.

Kernwoorde: veerkragtigheid, sosio-ekologiese sisteme, veerkragtigheids assessering benadering, versteurings, keerpunte, verantwoordelike benadering

PREFACE

This dissertation is the result of a search for meaning. In my heart I am a lifelong scholar and natural scientist, but this opportunity arrived late in my life. The past years I have learned that the boundaries between disciplines are diminishing and subject content becomes interlinked at a new level. May this research contribute to creating awareness of actions in the environment and to encourage sustainable actions in social-ecological systems.

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LIST OF ACRONYMS

Anglo Coal	British multinational mining company
Arcelor Mittal	Multinational steel manufacturer
CEM	Centre for Environmental Management
GDP	Gross Domestic Product
ESKOM	Electricity Supply Commission
EIA	Environmental Impact Assessment
IPPC	Intergovernmental Panel on Climate Change
NWA	National Water Act (36 of 1998)
NEMBA	National Environmental Management Biodiversity Act (10 of 2004)
NEMWA	National Environmental Management: Waste Act (59 of 2008)
NWU (Vaal)	North West University, Vaal Triangle Campus
OMNIA	National developer of fertilizers, specialising in nutriology
PAIA	Promotion of Access to Information Act (2000)
UK	United Kingdom
SASOL	South African Synthetic Oil Liquid
SES	Social-ecological system

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND RATIONALE

The purpose of this research study is to use the resilience assessment approach to evaluate the social-ecological system (SES) and thus determine the resilience status of the NWU (Vaal). The importance of focusing a study on the social-ecological system of the NWU (Vaal) is motivated as follows.

Human activities alter ecosystems faster and more extensively than any other natural phenomenon. The dynamic and ever changing environment requires management strategies that can cope with and adapt to change (Folke *et al.,* 2002:437). Traditional command and control approaches assume the environment to be a static system, making it more vulnerable by masking critical system properties that may be unnoticed before it is too late (Holling & Meffe, 1995:329). The resilience assessment approach uses strategic questions and activities to construct a conceptual model of a social-ecological system of a place of interest. Using the conceptual model, the guided assessment identifies potential thresholds that can contribute to or erode the system's resilience. A resilience assessment therefore may provide valuable insight into the developing strategies for buffering against or coping with both known and unexpected change in the environment (Resilience Alliance, 2010:4).

Universities are comparable to large commercial businesses regarding the consumption of energy, materials and pollution that occurs in lecture halls and research laboratories (Viebahn, 2002:3). Sustainable practices regarding the environment are expected from corporate businesses. Therefore, it may be reasonable to expect the same from universities (Disterheft *et al*., 2012:80).

James & Card (2011:166) state that universities need responsible leadership for the protection of society's environment and that higher education has the

unique academic freedom and exposure to critical thinking to do experiments in environmental practices.

In South Africa, Rhodes University reported in 2012 on a systems approach to mainstream sustainability at the university (Togo & Lotz-Sisitka, 2012). Internationally, the resilience assessment approach is mostly used on large, ecological systems and includes research studies in places like the Causse Mejan in France; the Coral Reefs of the Caribbean; the Spiny Forest in Southern Madagascar; the Everglades in Florida, USA; the Gorongosa National Park, Mozambique; the Goulbourn-broken Catchment, Australia; KristianstadsVattenrike in Sweden; Mae Ping River Basin, Thailand; Maine Fisheries, USA; the Malinau Region in Borneo; the Northern Highland Lakes District, Wisconsin, USA; Phoenix, Arisona, USA; Rangelands of New South Wales, Australia; the South-East Lowveld, Zimbabwe; and the Western Australian Wheatbelt in Australia (Resilience Alliance website, 2013). The use of the resilience assessment approach to assess a university campus is therefore unique.

Campus practice of environmental matters links both the operational aspect of teaching, research and institutional administration, with education. The latter provides opportunities to communities related to the university to learn, reflect and develop practices for the well-being of current and future generations in the environment (Disterheft *et al*., 2012:80).

1.2 BACKGROUND INFORMATION OF THE NWU (VAAL)

The NWU (Vaal Campus) is situated on the banks of a three kilometre stretch of the Vaal River in a nature reserve that hosts various animal and plant species, sharing the habitat with students and university staff. Being next to the river in Vanderbijlpark makes the NWU (Vaal) part of the Vaal Barrage Catchment. Thus part of the busiest water way in South Africa (Tempelhoff *et al*., 2007:110). The influence of this upper scale system, the Vaal Barrage, on the social-ecological system of the focal system, the NWU (Vaal), is worth exploring.

1.2.1 Spatial and temporal boundaries

The NWU (Vaal) is situated on the south-eastern part of the town of Vanderbijlpark. The town is part of the Sedibeng Municipality, but in November 2013 the newly emerged Vaal Metro Municipality was announced to be in control as the local sphere of governance. The position of the NWU (Vaal) in the region is indicated in figure 1.1. by A.

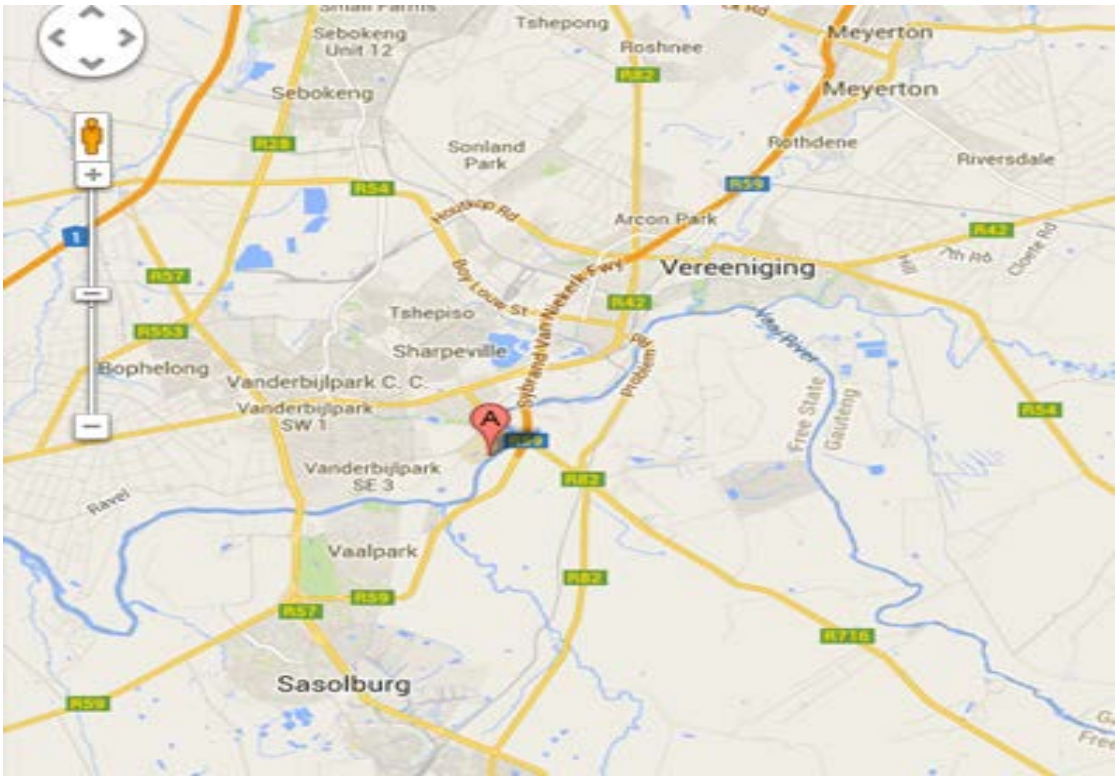


Figure 1.1: Map of the immediate region surrounding the NWU (Vaal) and its position in the Vaal Barrage Catchment (Google Maps, 2013)

The campus covers an area of 117 7974 ha or 117 7974 m^2. The increase in buildings, which the researcher assumes to be around 40% of the available land in 2013 is visible when comparing figure 1.2 (Campus plan, before 2010) and figure 1.3 (Campus plan, 2010 - 2020).

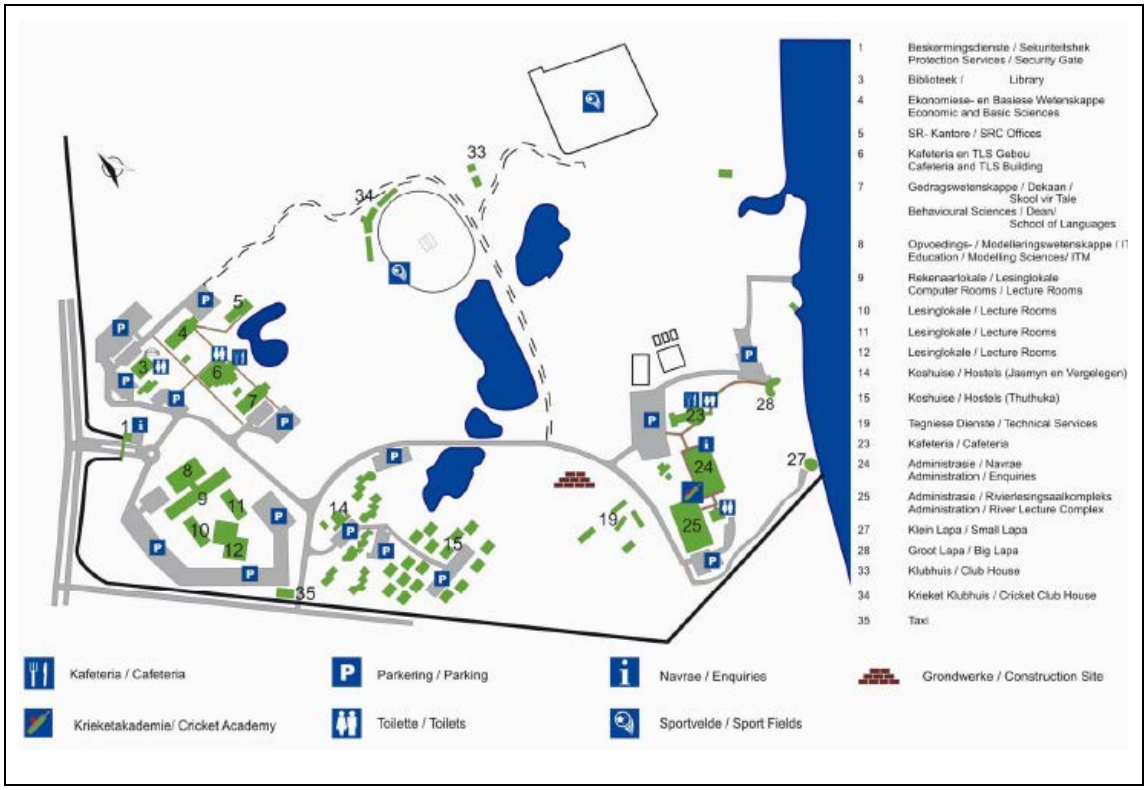


Figure 1.2: Campus plan of the NWU (Vaal) before 2010 (NWU website, 2013).

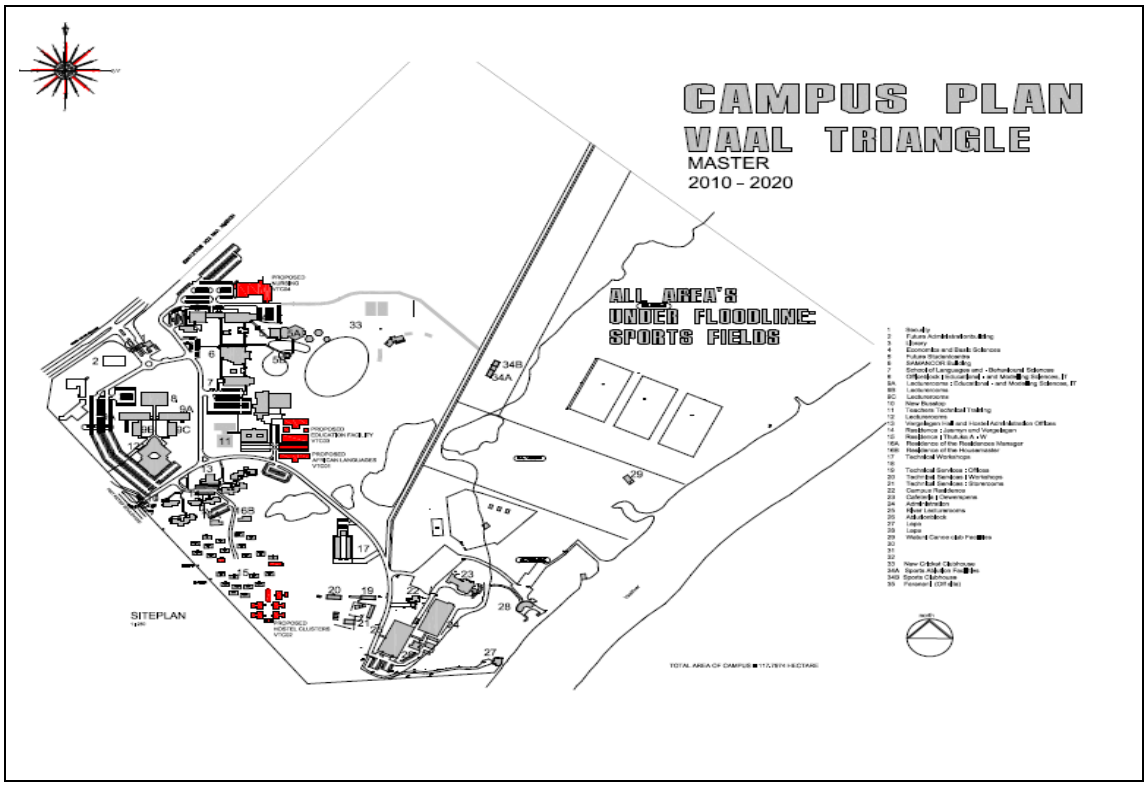


Figure 1.3: Campus plan of the NWU (Vaal) 2010 – 2020. (F. Basson, 2013).

1.2.2 The ecosystem

1.2.2.1 Abiotic characteristics of the focal system

As mentioned, the NWU (Vaal) is situated next to the Vaal River. The river flood line runs just beneath the administrative facilities (building 25) and includes some of the sports ground in the form of rugby fields. The slope from the river increases gradually. Standing at the river side the latest buildings are visible on ground level about 6 m higher than the ground level next to the river. From the river banks the drop to the water can be any measurement between 1 to 2,5 m.

1.2.2.2 Biotic characteristics of the focal system

The grounds of the NWU (Vaal) are covered with diverse vegetation. Near the river, on the eastern part of the campus there are indigenous as well as alien trees, some of which are more than hundred years old. Various alien and invasive plant species, such as oleander, blue gums, pines, poplars, pampas grass and willows are found on the campus (NWU, 2012).

Planted grass, covered most of the river bank to make it a good venue to sit and relax. Alien blue gum trees, which were planted when the grounds were still farmland, form woods near the river. In these woods no grass or smaller vegetation grows at the ground level due to limited sunlight. Most of the area under these trees is covered with residue from the trees like bark and old, decaying leaves. These woods serve a hiding place for the various wild life and also plays an important part during the birth procedure of young off spring (Scholtz, 2013). The following photographs reveal the biotic character of the NWU (Vaal) as observed by the researcher in November 2013.

Figure 1.4: Photographs of the biotic components at NWU (Vaal) (Muller, 2013; Willemse, 2013).

The north western part of the campus is covered with grass lands as well as sports fields. Rugby, soccer and cricket fields consisting of planted grass are found here. Indigenous trees like the white stinkwood (*Celtis africana)* are planted yearly by campus management. Locally the exotic white stinkwood, (*Trema orientalis)* is also found. *Trema orientalis* is not as widely distributed, or as tolerant of tough conditions as *Celtis africana*. Also, *Trema orientalis* leaves tend to be larger and more slender, serrated nearly from the base, and the female flowers and fruit are carried on much shorter stalks than those of *Celtis africana* (Plantzafrica, 2014).

Invasive and alien plant species are controlled by using the services of an outside contractor (Basson, 2013; Annexure F).

Man-made dams filled with water from the Vaal River, accommodate various indigenous fish species like barber and yellow fish (Scholtz, 2013). Wildlife found on campus includes springbok (*Antidorcas marsupialis*), blesbok

(*Damaliscus pygargus*), gemsbok (*Oryx gazelle*) and black wildebeest (*Connochaetes gnou*) (NWU, 2012). A variety of bird species, as well as the well-known campus geese, completes the animal biodiversity spectrum.

A legal compliance audit, conducted in 2012 by the Centre for Environmental Management (CEM) of the NWU (Potchefstroom) (NWU, 2012) revealed non-compliance with a variety of environmental issues. All environmental management issues at the NWU (Vaal) are currently managed by the campus's Technical Services. There is currently no available environmental management policy for the NWU (Vaal). During the last five years the campus has had a large influx of students and to accommodate the latter, new buildings have been built in order to supply available space to teaching, learning and housing activities. For biodiversity on campus, the increase in humans and less available land are not always favourable. By using the resilience assessment approach the researcher hopes to gain clarity on the abovementioned issues and to deliver a contribution as a concerned, social responsible worker regarding environmental resilience at the NWU (Vaal).

1.3 APPROACH TO THE RESEARCH STUDY

The researcher has followed a learning based approach in this research by incorporating both interior and exterior evidence to get a holistic view of the field of study (Du Plessis, 2008:70; Gunderson, 2009:11). The learning based approach has allowed the researcher to adjust her focus on the topic when new evidence has been revealed. The use of multiple sources during data collection has aided in finding relevant data for a specific scenario.

1.4 PURPOSE STATEMENT

The intent of this exploratory, mixed method research study will be to evaluate the social-ecological system and thus determine the resilience status of the NWU (Vaal) by using the resilience assessment approach. In the first qualitative phase, a literature review revealed concepts like resilience, the adaptive cycle and panarchy, social-ecological system and the methodology of the resilience assessment approach. Data, qualitative and quantitative, has been collected via interviews, observations and document reviews, as well as

the resilience assessment approach to explore the resilience of the social-ecological system of the NWU (Vaal).

1.5 RESEARCH QUESTIONS

The following primary research question has guided the research:

What is the resilience status of the social-ecological system of the NWU (Vaal) as revealed by the use of the resilience assessment approach?

The following secondary questions unfold within the central question:

- Which possible disturbances erode ecological resilience at the NWU (Vaal)?
- Is it possible to construct a conceptual model of the social-ecological system of NWU (Vaal) as encouraged by the resilience assessment approach?
- Is it possible to use the resilience assessment approach on a small scale ecosystem like the NWU (Vaal)?

In order to answer the main question it is necessary to apply the resilience assessment to the NWU (Vaal). The first of the secondary questions helps to identify the components, the dynamics and the social aspects of the system. The latter two of the secondary questions are answered after completion of the resilience assessment approach. Key concepts, which aim to simplify interpretation, are discussed in more detail in 1.6.

Conceptual framework

This study has been conceptualized in terms of and based on the following conceptual framework as depicted in Figure 1.5:

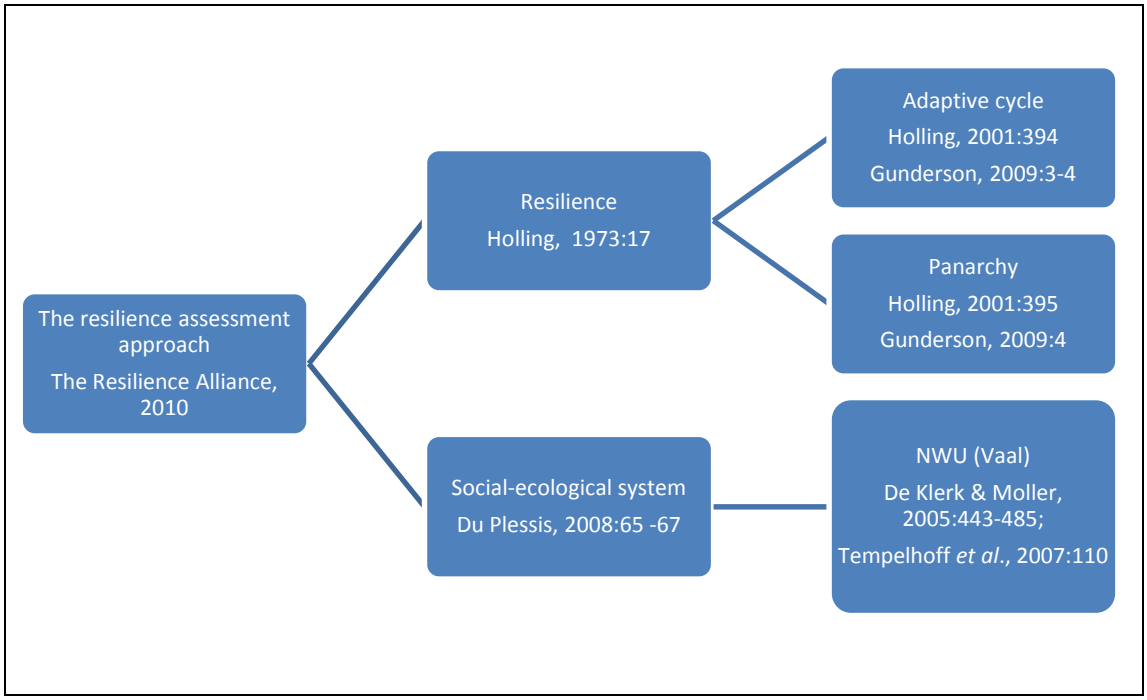


Figure 1.5: Conceptual framework of the research study

1.6 KEY CONCEPTS

The following key concepts are defined.

The resilience assessment approach

The resilience assessment approach consists of strategic questions and activities which guide the researcher to construct a conceptual model of the social-ecological system of NWU (Vaal). Available natural resources impact on the environment, stakeholders and governance issues are taken into account to identify potential thresholds and factors which contribute or erode the resilience of the focal system (Resilience Alliance, 2010:4).

Resilience

Resilience is formulated as the capacity of a system to persist within a state in the face of change. It is proposed that resilience is determined by the persistence of relationships within a system and therefore an ability of the system to absorb changes at a variety of levels (Holling, 1973:17). Resilience is enhanced by green spaces, participation of diverse groups and networks (Tidball & Krasny, 2007:154; Gunderson, 2009:10).

Adaptive cycle

Adaptation is a re-activity of a social-ecological system and links with reaction on exogenous circumstances. The adaptive cycle is used to demonstrate temporal change in a social-ecological system in a figure by four phases (Holling, 2001:394; Gunderson, 2009:3-4).

Panarchy

Panarchy indicates how variables at different scales interact to control the dynamics and trajectories of a social-ecological system. It is therefore a theory, which suggests that abrupt changes occur as a result of interaction between slow and fast variables of successive adaptive cycles (Gunderson, 2009:5).

Social-ecological system

Social-ecological system refers to a dynamic, integrated living system consisting of agents (humans and other), their actions and behavioural patterns interacting in a physical environment. This single, integrated system expands across matter, life and mind and incorporates human, social and cultural phenomena. Social-ecological systems are studied to improve understanding and aid decision making and problem solving in matters related to systems management. It indicates how systems deal with change and support the likelihood of successful interventions to promote sustainability of the system (Du Plessis, 2008:67).

1.7 SEQUENCE OF RESEARCH

This research is organized in five sections. After the introduction, the research methodology is introduced. Chapter 3 contains the literature review, as part of the data collection, as well as the construction of the time line of the focal system. The findings from the resilience assessment approach, incorporating valuable information from document reviews and interviews with relevant role players, as well as observations by the researcher, are revealed. Finally, the significant conclusions about the conceptual model of the NWU (Vaal) and the stewardship strategy are discussed.

1.8 POSSIBLE CONTRIBUTIONS OF THE STUDY

The researcher hopes that results from this research study will guide environmental practice at the NWU (Vaal) and that the proposed stewardship strategy can be used to allow more role players to participate in sound environmental practices on campus and at the NWU as an institution.

1.9 CHAPTER SUMMARY

This chapter reveals why and how the researcher has chosen the topic of research and the rationale behind the choice (*cf*. 1.1). A purpose statement and related research questions (*cf*. 1.4) have been formulated to guide the research. The conceptual framework (*cf*. 1.6) explains key concepts in the research. In chapter two the research methodology is explained.

CHAPTER 2

RESEARCH METHODOLOGY

2.1 INTRODUCTION

Chapter 2 elucidates the decisions made in conducting the research regarding the following aspects:

- Research paradigm
- Literature review
- Research design
- Research strategies
- Data collection methods
- Rigor
- Data analysis and
- Complying with ethical principals

2.2 RESEARCH PARADIGM

Research is a process to obtain scientific knowledge by using different objective methods and procedures. Research cannot be conducted in a vacuum and researchers investigate issues from a certain position of knowledge.

This research study was proposed from a pragmatic view, with emphasis on the research problem, namely to interpret the concept of resilience and what the resilience assessment approach implies. This research study was conducted in a specific social and time bounded context, namely from March 2013 to December 2013, at NWU (Vaal) (Creswell, 2009:11). The unit of analysis during this research was NWU (Vaal) (Yin, 2009:29).

Creswell (2009:11) indicates that the pragmatic paradigm is concerned with applications and solutions to problems. Using a pluralistic approach to derive

knowledge about problems, it is best presented by the mixed method research design. Pragmatic researchers emphasize the research problem and use all available approaches to understand them. For pragmatists, the truth is what works at the time and they look at the how and what of research.

2.3 EMPIRICAL RESEARCH

2.3.1 Literature review

Previous research on the topic of ecological resilience provided facts and background information and gave insight regarding resilience, as well as the adaptive cycle, panarchy, social-ecological system and the resilience assessment approach. Literature highlights that the use of the resilience assessment approach is widely accepted for a larger social-ecological system but not on university campuses.

Databases like Ebsco Host, Academic Search Premier, Eric, JSTOR and Science Direct were used to link with authoritative environmental journals to ensure valid and reliable research. Key words like resilience, adaptive cycle and panarchy, social ecological systems and the resilience assessment approach were used.

2.3.2 Research design

Creswell (2009:5) indicates that a research design refers to the plan or proposal to conduct the research and involves the elements of philosophy, strategies of inquiry and specific methods. Research design is therefore planning and the goal of sound research design is to provide credible results (Leedy & Ormrod, 2005:86).

Research designs can be either qualitative, quantitative or a mixed methods design. The researcher used mixed method research and will motivate the choice.

2.3.2.1 Mixed method design

Mixed method studies combine both qualitative and quantitative approaches to research in a single project. It uses triangulation as a way to combine both approaches at different phases in the research process (De Vos, 2005:361).

In this research a sequential, exploratory mixed method design was used as both quantitative and qualitative characteristics were incorporated in the research study. The first phase of qualitative data collection and analysis were done through the literature review and composition of the historical time line in respect of the social-ecological system of NWU (Vaal). The use of the resilience assessment approach introduced the quantitative phase of data collection and analysis. Both the first qualitative phase and second quantitative phase were seen as equally important and data was mixed between the qualitative data analysis and the quantitative data collection. The quantitative data collected in the second phase aided to interpret the findings of the qualitative phase (Creswell, 2009:211).

Figure 2.1 explains the research design in terms of timing, mixing and weighting.

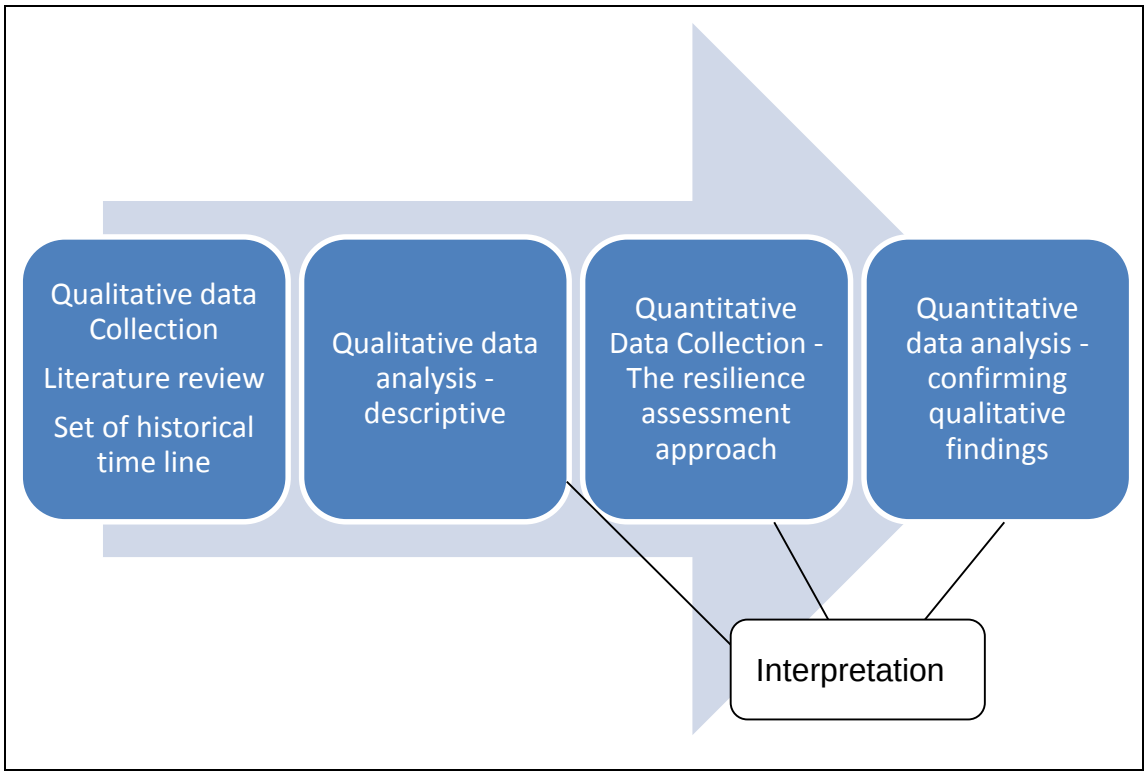


Figure 2.1: Exploratory mixed-method research

Advantages of a mixed method design include an in-depth exploration of the topic being studied which leads to better understanding. The sequential, exploratory mixed method design is useful to explore the phenomenon of resilience and aids the researcher to expand on qualitative findings. Disadvantages of this design include a prolonged time to complete both data

collection phases and decisions to be made during the qualitative phase regarding the focus of the research (Creswell, 2009:212).

2.3.3 Research strategies

In the process of exploring an approach like the resilience assessment an interactive, deductive case study-type approach was used.

Yin (2009:18) refers to a case study as an empirical inquiry that investigates a contemporary phenomenon in depth and in real life context. Nieuwenhuis (2007:75) agrees with Yin and indicates that case studies investigate contemporary phenomenon within a real-life context with the use of multiple sources of evidence. A holistic and deep understanding of the dynamics of the phenomenon being studied directs the research.

Strengths of case studies include the use of multiple sources and techniques in the collection and analysis of data. Data gathered through case studies is mainly qualitative, but may include quantitative data (Nieuwenhuis, 2007:76). Yin (2009:18) indicates that case studies benefit from the prior development of theoretical prepositions that guide data collection and analysis, as with the case of the resilience assessment approach.

Theory development according to Yin (2009:35, 37) is essential for a case study with the purpose to test a theory like the resilience assessment approach. The resilience assessment approach can be viewed as an organisational theory of a social-ecological system. A case study suited this research as the main aim was to use the resilience assessment approach to evaluate the social-ecological system and thus determine the resilience status of the NWU (Vaal). The notion was never to generalize findings, but focused on the social-ecological system of a specific campus.

2.3.4 Data collection methods

This research was carried out in a real life situation with the researcher as an instrument in the process of gathering data.

2.3.4.1 Sampling

Sampling refers to the selection of a portion of the population to acquire data. To obtain rich and suitable information, documents and participants were purposively chosen (Nieuwenhuis, 2007:79).

2.3.4.2 Data gathering techniques – methodological steps

Data was collected during this research study through the use of the resilience assessment framework, document reviews, interviews and observations. The **three principles** of Yin (2009: 114-124) were followed during data collection namely

(a) **the use of multiple sources** of evidence to reach convergence of evidence by data triangulation, meaning that the events or facts of the case study were supported by more than one source of evidence;

(b) to **create a case study database**. Data which was collected was stored in an evidentiary data base like the time line, as a result of the resilience assessment approach and in the form of notes from interviews and photographs representative of observations. This report from the research, commented on the findings from the data as seen in the second part of the data collection;

(c) **to maintain a chain of evidence** the findings from the research cited the specific data collected; actual evidence and the circumstances of data collected like time and place were revealed and the circumstances under which data was collected, related with case study protocol.

The researcher acted as an instrument in the collection of data by examining documents, observing practices on campus and interviewing participants, therefore becoming part of the research process (Creswell, 2009:175).

In the following section different data gathering techniques are discussed.

Resilience Assessment framework

The following methodological steps have been adapted from the framework. The resilience assessment framework focuses on tools to develop a conceptual model of the NWU (Vaal) social-ecological system.

Step 1: Describing the focal system through the key resource uses, ecosystems services, and critical disturbances

The first step is to address two critical questions relating to the focal system namely “Resilience of what?” and “Resilience to what?”

To answer the first question the social-ecological boundaries and components of the focal system were defined. Key natural resources and the services provided by natural resources, as well as stakeholders relying on natural resources, were identified. The scope of the research was narrowed down to incorporate only relevant key components to the social-ecological system on campus.

In order to answer the second question “Resilience to what?” the critical causes of disruptive events in the focal system were identified. These disturbances, which can be natural or human-caused, were characterized by their frequency, severity and predictability.

Both the space and time scale of the focal system were expanded to a scale above the focal system. The development of a historical timeline from the 1980s up to 2010s was based on relevant events of significance to the social-ecological system under investigation. The most critical interactions in both space and time were identified.

Step 2: Understanding the system dynamics: change drivers, alternative states, and thresholds

Evidence from the historical timeline in the first step revealed the key factors that drive change in the focal system. Key variables that could be used as indicators of change were determined. Thresholds and possible transitions of the focal scale were indicated in relation to the smaller and upper scale.

Next, identification of the phase of the adaptive cycle in which the focal system operated was done. The current state of the focal system was described according to key components and the relationships among them. This process was repeated to describe the historical state and a potential future state. Lastly, descriptions of the changes in key components that cause a shift to alternative states of the focal system were described.

Step 3: Describing governance and social networks in the focal system

The identification of governance, formal and informal institutions relevant to decision-making of the focal system was made. By taking into account the environment, the scale of the decision-making processes (on campus, municipal, provincial, national) was identified. The effectiveness of rule compliance and enforcement in terms of effectiveness were described and lastly the relation between the institutions mentioned, with existing conflicts and conflict resolution mechanisms were noted.

Mapping of the social networks in a simplified sketch indicating the contact between stakeholders involved in the focal system was followed by a basic analysis regarding the relation between groups in the network.

Step 4: Constructing the conceptual model of the social-ecological system of NWU (Vaal).

The key findings regarding resource uses, ecosystems services, and critical disturbances were summarized on a conceptual model of the focal system. The conceptual model is simple for the sake of clarity in this research study and is not the focus of the research.

Step 5: Describing the status and trend of factors that contribute to resilience of the NWU (Vaal Campus).

Evaluation of the focal system revealed if the system has developed the factors which increase resilience on campus. Strategies and activities which enhance resilience were proposed and relevant challenges that hinder implementation were mentioned (Delgado, 2013:15-17; Resilience Alliance, 2010).

Document reviews

To construct the historical timeline the researcher relied on documents that date back to the 1960s when the NWU (Vaal) was founded. These documents included information on available land, student numbers and biodiversity, and also indicated major events regarding climate and weather.

Interviews

Interviews are seen as a two-way conversation in which the researcher aims to see the world through the eyes of the participant, therefore obtaining rich, descriptive data that helps to understand the participant's construction of knowledge and social reality (Yin, 2009:107). The value of semi-structured interviews is that it: defines the line of inquiry; seldom spans a long time period; requires participants to answer to a set of predetermined questions; and allowing time for probing and clarification of answers (Nieuwenhuis, 2007:87).

Semi-structured interviews, with the set of predetermined questions, were conducted with different participants in key positions relating to environmental management on the NWU, Vaal Campus like the Director of Technical Services, the Food Service Manager of the cafeteria (also in control of animal diversity on campus), and the vice rector, Prof Linda du Plessis. The interviews were recorded with a digital recording device and notes were taken at the time of the interviews (Annexures G to K).

Observations

Observing is a systematic process of recording the behavioural patterns of practices without necessarily communicating or questioning it. Observations help researchers to gain deeper insight and understanding of phenomena under observation and are a selective and subjective practice. Observations tend to focus on specific practices, and the researcher needs to be conscious of his or her own biases and design of ways to deal with them (Yin, 2009:109).

The researcher acted as a participant, observer where the researcher became part of the research process, having an insider perspective on it and aimed at understanding the social-ecological system of the NWU (Vaal) (Nieuwenhuis, 2007:85; Yin, 2009:111).

The focus of the observation in this research was to observe practice relating to environmental management in real life context. The focus of the researcher was on practices related to resilience like energy and water use as well as

waste management and recycling and the real state of the natural environment on campus.

To record the observations, field notes were taken that indicate the date and time, situation, actions observed, as well as the reflection of the researcher. Photos were taken at relevant spots to enhance the description of the observation. Mr Johan Strauss, Geography lecturer in the School of Education, acted as a co-observer and confirmed observations during the field trips.

2.3.5 Trustworthiness of the study

The quality of the research strategy depends on the concepts of validity and reliability.

Construct validity was ensured by using multiple sources of evidence during data collection like documents, interviews and observations and by reviewing the report based on recommendations by the study leaders.

Internal validity was reached during data analysis by doing explanation building, using the resilience assessment approach and constructing the model of the social-ecological system of NWU (Vaal).

External validity during research design was affirmed by using the theory of the resilience assessment approach.

Reliability during data collection was reached by applying case study protocol and developing a case study database with the historical time line (Yin, 2009:41; 114). Reliability is also enhanced by maintaining a chain of evidence (*cf*. 2.3.4.2) and allowing external observers and the supervisors, to trace the chain evidence (Yin, 2009:123). A co-observer confirmed observations, thus increasing reliability.

2.3.6 Data analysis

Yin (2009:130) proposes four general strategies for the data analysis of a case study namely:

(a) reliance on a theoretical proposition;

(b) developing a case description;

(c) the use of both qualitative and quantitative data; and

(d) the examination of rival explanations.

In this research study all the strategies were used. Reliance on theoretical propositions was reached through the use of the resilience assessment framework as a guideline for the study. A case description was dealt with by the synthesis of both the historical timeline and conceptual model of the social-ecological system (NWU, Vaal). The mixed method research design opted for both qualitative and quantitative data collected.

Analytic techniques used include (a) pattern matching using evidence from the historical timeline, interviews and observations (Yin, 2009:136); (b) explanation building to set the historical timeline and explaining the influence of events on the environment (Yin, 2009:141); (c) the use of the Resilience Assessment framework which guide the process to understand resilience at the NWU (Vaal Campus) as a social-ecological system.

2.3.7 Complying with ethical principles

Creswell (2009:88) indicates that it is important to identify a problem that will benefit the individuals who participate in the research, in order for the research to be beneficial for others beside the researcher.

The researcher adhered to the following ethical guidelines by Creswell (2009:89-91):

- She obtained permission for the research study to be conducted on the NWU, Vaal Campus from the rector, Prof T. Mariba (*cf.* Annexure A).
- She obtained permission from the Institutional Office to use data regarding student and staff numbers (*cf*. Annexure B).
- She revealed to all participants and respondents her identification, the reason for their selection in the research and the interviews, expected benefits they could experience from the research, and how and why they were involved.
- In the write-up the researcher did not falsify findings or invent findings for her own needs. The researcher wanted to release the findings of this

research study in detail so that other researchers in the same study field can determine the credibility and merits of the study.

2.4 CHAPTER SUMMARY

A literature review was used to identify gaps in current research, and emphasized what has been done and how it is done, therefore methodology, in the related subject. The researcher wanted to contribute to the campus's environmental management and therefore chose a hands-on approach in the research design. A mixed-method approach was chosen and the researcher used document reviews, interviews, observations, as well as the resilience assessment approach to collect data. Using a purposive sample to obtain rich data, deductive content analysis was used to analyse data. In Chapter 3 the literature review and set of a historical timeline regarding the social-ecological system of the NWU (Vaal) form part of the data collection.

CHAPTER 3

LITERATURE REVIEW

3.1 INTRODUCTION

The World Summit on Sustainable Development (WSSD) was held in Johannesburg, South Africa from 26 August to 4 September 2002. A report delivered during this summit on behalf of the Environmental Advisory Council of the Swedish Government, indicated that human and natural systems cannot be treated independently and the response of ecosystems to human use is never linear, predictable and controllable (Folke *et al*., 2002:437). The ideal of sustainable development, which was promoted during the World Summit on Sustainable Development (WSSD), originally caught the attention in 1987, at the time of the publication of the Brundtland Report. At the time sustainable development was perceived as a concept aimed at promoting an understanding of creating and maintaining prosperous social, economic and ecological systems. These systems are interlinked with humankind that in turn, rely on ecosystems services for clean water, air, food production and fuel. However, humans are also responsible for the transformation of ecosystems in less favourable conditions, making the ecosystems unable to provide services with an increase in its vulnerability and the loss of livelihoods and security. The latter is known as a loss in resilience (Folke *et al*., 2002:437).

The emphasis is on the urgency for universities to attend to environmental activities on campuses and to incorporate management practices that enhance learning and protect the environment. University campuses are common ground for students and university personnel, sharing the immediate environment with a variety of other species. Events that have an impact on humankind influence the environment and vice versa.

Focusing only on the non-compliance environmental issues, support command and control approaches that are rigid and linear and implicitly

assume that problems are well-bounded, are clearly defined and relatively simple regarding cause and effect. Research studies indicate that a style of environmental management that uses command and control approaches create hardened conditions in the social-ecological system. They erode resilience and finally promote the system's collapse (Folke *et al*., 2002:438; Holling & Meffe, 1996:329).

Focusing on resilience supports an approach that is more flexible and open to learning. Attending to slow-changing, fundamental variables that create memory, legacy, diversity and the capacity to innovate both social and ecological components of the system conserves and nurtures diverse elements necessary to reorganize and adapt the system after disturbing events (Folke *et al*., 2002:438).

Figure 3.1 indicates the rapid increase in student and staff numbers during the last six years. The increase in student numbers created a demand for infrastructure in the form of residences for students, as well as lecturing and recreational facilities.

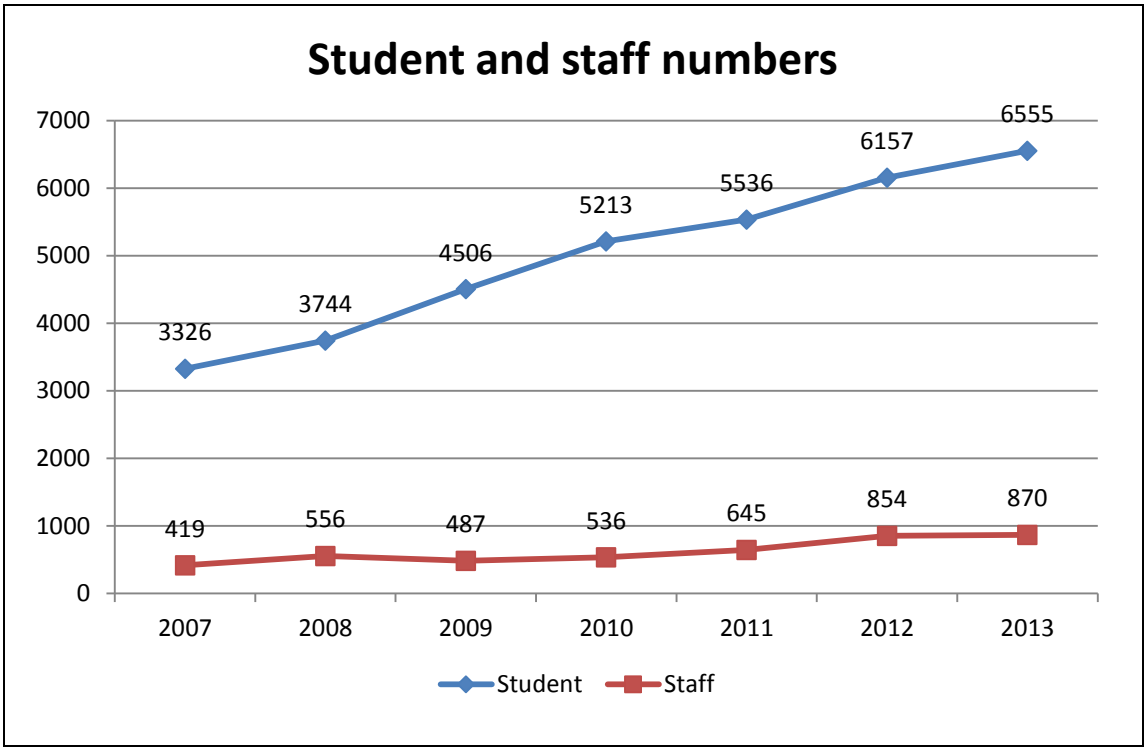


Figure 3.1: Graph of increased student and staff numbers from 2007 to 2013 (Jordaan, 2013)

In order to determine the resilience of social-ecological systems at the NWU (Vaal), a description of what resilience implies will be given and the relevance of the resilience assessment approach to assess practices regarding social-ecological systems at the NWU (Vaal) will be explored in this chapter.

The literature review addresses the conceptual framework in figure 3.2.

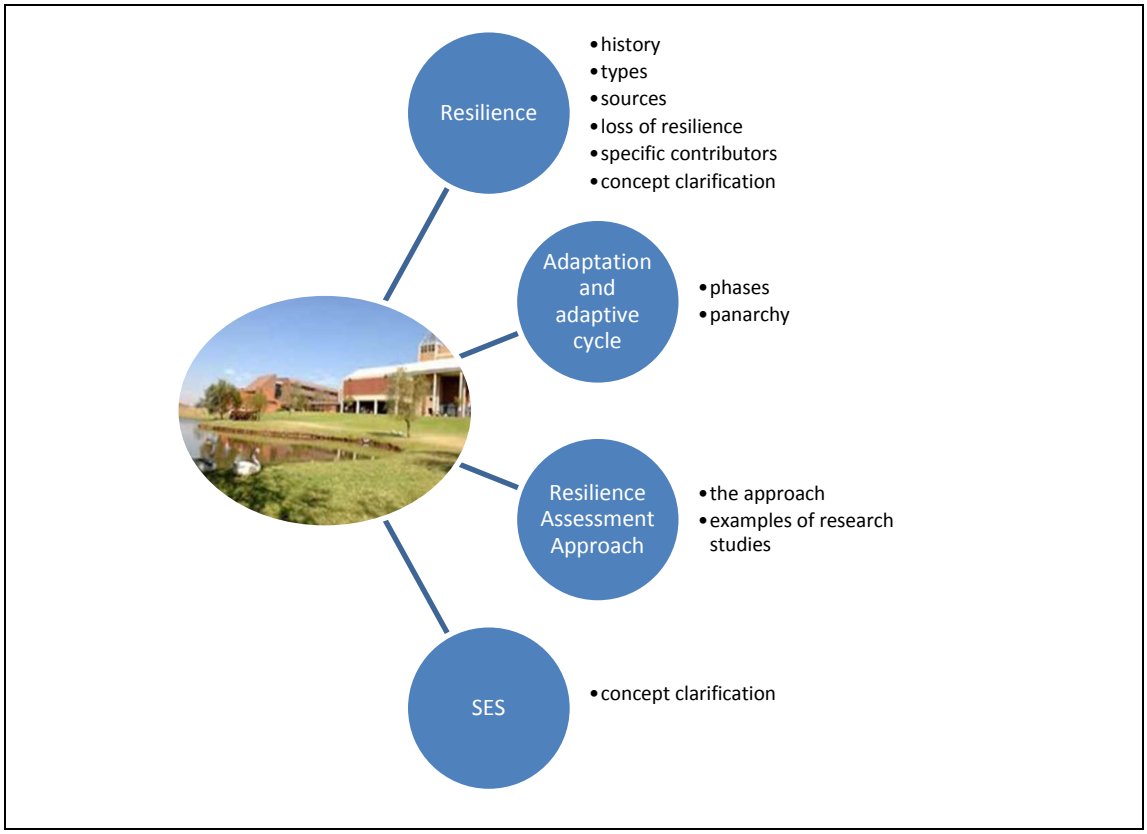


Figure 3.2: Conceptual framework of the literature review

3.2 THE CONCEPT RESILIENCE

3.2.1 The history of the concept resilience

Resilience can be traced back to the Latin word “resalire” which means walking or leaping back. The concept of resilience emerged from ecology in the 1960’s and early 1970 via studies of interacting populations like predators and prey relationships (Holling 1973:1; Holling, 1961 cited in Folke 2006:254). Holling is therefore seen as the father of the concept of resilience in ecology. Holling (1973:2-6; Gallopin, 2006:297) introduces the existence of multiple stability domains or multiple basis of attraction in natural ecological systems and how these domains relate to ecological processes, random events and

heterogeneity of temporal and spatial scales. Holling formulates resilience as the capacity of a system to persist within a domain in the face of change and proposed that resilience determines the persistence of relationships within a system. Resilience is therefore a measure of the ability of a system to absorb changes at a variety of levels and variables and still persist (Holling, 1973:17).

Resilience research, in terms of Holling's approach, relies on low-density data and understanding of a multi- scale state rather than an overload of data. Multi-stable states are characterized by high variability, surprise and unpredictability. The size of stability domains, which indicates the amount of disturbing events that a system can take before control shifts to another set of variables and relationships, is a useful measure for resilience (Folke, 2006: 254).

Holling (1973:9) reports that the response of a system depends on its stability properties. Small events within a particular range can be absorbed by the system without visible change. Then one additional increment can flip the system into a totally different mode of behaviour. Holling argues that a social-ecological system is not static or completely determined. Variability and change of social-ecological systems are constant companions. Boundaries of systems are tested and variables are continuously on the move. Resilience is therefore a property that allows a system to absorb and utilize, even benefit, from change.

The resilience perspective was applied first by only ecology research groups, but later fields outside the normal like anthropology, environmental psychology, cultural theory, management and social sciences were influenced before it became the theoretical foundation for active adaptive ecosystem management (Folke, 2006:255).

Holling (1986:459-460) after performing research studies on large scale ecosystem management, noted that key features of ecosystems include at least three sets of variables, each operating at qualitative different speeds; essential interaction across space and time that covered at least three levels of magnitude; and inevitable multi-stable states with surprise as the consequence.

Population ecologists, Tousa and Connell (1985), challenged Holling to provide evidence to prove the existence of multi-stable states. The work of Carpenter *et al.* (2001) and Gunderson and Pritchard (2002) introduced the significance of slow variables and slow-fast interactions in ecosystem dynamics and confirmed therefore multi-stable states proposed by Holling in 1973 (cited in Folke, 2006:256).

The last word has not been written on defining resilience as a concept. Studies in multiple research fields still contribute exponentially towards expanding the concept. The next section addresses types of resilience.

3.2.2 Types of resilience

Resilience of social-ecological systems has been defined in two distinct ways emphasizing two different aspects of the concept. Equilibrium resilience is defined as the stability of a system near an equilibrium steady-state, where resistance to events and the speed of return to the equilibrium are used to measure the resilience (Pim, 1984; O'Neill *et al*., 1986; Tilmand & Downing, 1994 cited in Holling & Meffe, 1996:33). Equilibrium resilience focuses on efficiency, constancy and predictability that are all attributes of command and control approaches with a fail-safe design. Engineering resilience up to the present time still supports this single equilibrium view and focuses on maintaining an effective functioning, constancy of a system and predictability of a near single steady state (Folke, 2006:256). This is not a very desirable option for exploring resilience. It is considered to be static and too much intent on a mechanistic approach towards social-ecological system.

Ecosystem resilience, on the other hand, emphasizes conditions far removed from any equilibrium. Instabilities can flip a system into another regime of behaviour and into another stability domain (Holling, 1996:33; Gunderson, 1999:3). Ecosystem resilience indicates the magnitude of events or stresses that can be absorbed or accommodated before the system changes its structure by changing the variables and processes that control the system's behaviour. Ecosystem resilience focuses on persistence, change and unpredictability – typical attributes of an adaptive management system (Holling, 1996:33).

Walker *et al.* (2002) support the concept of ecosystem resilience definition when they suggest that resilience is the potential of a system to remain in a particular configuration and to maintain its feedbacks and functions. Building resilience of a desired system requires enhancement of structures and processes in social, ecological and economic context that enable the system to reorganize after an event and reducing effects that tend to undermine it.

The Resilience Alliance (2010:5) also agrees with Holling and Meffe when they formally define resilience as a system property that indicates the magnitude of change or events of change a system can experience before shifting into an alternate state with different structural and functional properties.

For the purpose of this research study, the concept of ecosystem resilience as clarified by Holling (1973 & 1996) and supported by Walker *et al.* (2002) and The Resilience Alliance (2010) is accepted.

The question now arises: "What contributes to resilience and what erodes resilience in a social-ecological system?"

Section 3.2.3 and 3.2.4 provides some answers.

3.2.3 Sources of resilience

Biodiversity adds to the self-organizing ability of complex adaptive systems to absorb disturbing events and reorganize the system for future events (Folke *et al.*, 2004:570-572). The number of species is not the main contributor to resilience in a system, but rather the existing groups of species, or functional groups in various forms like predators, herbivores, pollinators, decomposers, nutrient transporters which have all different and overlapping properties in relation to physical processes (Bellwood *et al*., 2004:4-5: Walker *et al*., 1999:109-110).

Seemingly redundant or unnecessary species can be critical in the reorganization of the system after disturbing events. The connection of habitats by redundant species on different scales can reinforce functions across scales and increase system resilience (Holling, 1992:494). Therefore it

is possible to argue that dominant species do not necessarily contribute to changes across scales in social-ecological systems

Tidball and Krasny (2007:1) indicate that the participation of diverse groups, resource users, scientists and management personnel in decision making and structuring of a social-ecological system, is seen as diversity that aids to retain function and control over the social-ecological system, therefore adding to resilience. Social diversity indicates positive feedback loops which are identified as the strengths, skills and resources that are already in place within a social-ecological system.

Networks are the term Gunderson (2009:10) uses to indicate different forms of diversity in a social-ecological system. The researcher identified two types of networks namely, those that facilitate the flow of resources and ideas and those that facilitate connections among humans in a social-ecological system Gunderson (2009:9) also indicates that buffering can increase resilience by aiding systems to adapt over time mechanisms to protect it from or lessen the impact of disturbing events.

3.2.4 Loss of resilience

The loss of resilience and the flip of a social-ecological system in an alternative state are seen as the manifestation of surprise. Ecological surprise is a qualitative disagreement between the behaviour of the ecosystem and human expectations. Three types of surprises are known. They are local surprise that is unexpected discrete events; cross-scale surprise indicates discontinuities in long term trends; and true novelty, the emergence of new information in a social-ecological system (Gunderson, 2009:10).

According to Gunderson (2009:8) resilience can also be eroded by multiple mechanisms, like the stabilizing of key elements; the changing of pathways in systems by constructions; and a shift in key controlling processes through natural capital.

The next section addresses possible contributors of resilience on the NWU (Vaal Campus).

3.2.5 Possible contributors of resilience at the NWU (Vaal Campus)

Tidball and Krasny (2007:154) indicate that green space, like that at the NWU (Vaal), has the ability to reduce domestic violence, quicken healing times and reduce stress by improving physical health and bring cognitive and psychological benefits to people. They indicate that green spaces are often used to aid soldiers and victims of war to nurture their well-being. Green areas foster a sense of safety and belonging, therefore representing resilience by resisting not only ecological, but also social, psychological, political and economically harsh conditions. Green spaces also contribute to landscape heterogeneity with a variety of genetic, species and landscape diversity.

The sports grounds and green areas between lecture halls at NWU (Vaal) create a safe space for young adults to socialize and participate in uplifting activities. Cultural events held on the premises, as well as sport activities like rugby, soccer, netball, cricket and canoeing contribute to the constructive use of students' leisure time to relax, exercise and enjoy nature, while preparing themselves for future participation in society (Tidball & Krasny, 2007:157).

Tidball and Krasny (2007:156) propose that the value of diversity in nature can be seen as a parallel to human diversity. Differences in ethnic background, culture and language may benefit a social-ecological system. At NWU (Vaal) students, irrespective of race, religion or nationality share the same ecological space with limited negative events.

In the next section the concept of resilience is clarified.

3.2.6 Concept clarification on resilience of a social-ecological system

Resilience is not only persistence of a system or the maintenance of desired system characteristics in times of change, but also about the opportunities that arise in terms of reorganization of structures and processes to renew the system. The provision of adaptive capacity that allows for continuous development is inherent to a resilient system (Folke, 2006:259).

Carpenter (2001:777), Folke *et al.* (2002:438) and Tidball and Krasny (2007:149) reason that resilience for a social-ecological system is related to three attributes. They are: the magnitude of shock a system can absorb and still remain within a given state; the degree to which the system is capable to self-organizing; and the degree to which the system can build capacity for learning and adaptation.

Useful tools, according to these researchers, for resilience building, include structured scenarios and active adaptive management. Structured scenarios are seen as the envisioning of alternative futures and pathways that aid to attain or avoid particular outcomes. Active adaptive management agrees on a social context that is flexible and open, with a multi-level governance system that allows learning and increase the capacity of the social-ecological system. The concept of learning through adaptive management is discussed in more detail in section 3.3.

3.3 THE ADAPTIVE CYCLE AND PANARCHY

3.3.1 The adaptive cycle

Adaptation is the process of structural change in response to external circumstances. Adaptation is therefore a re-activity and linked to exogenous circumstances, while resilience is an inter-active and dynamic property of a social-ecological system (Young *et al*., 2006:305). The reaction of a social-ecological system to these external circumstances, better known as disturbing events, is visible as a cyclical movement through different spatial and temporal scales namely the adaptive cycle.

The adaptive cycle is a metaphor for the temporal change in a social-ecological system. A social-ecological system exhibits four distinct and usually sequential phases of change in structure and function.

A growth phase (*r*) emerges when the system starts. This phase is characterized by a rapid accumulation of structure, like an increase in biomass and complexity. The growth phase is also known for strong competition for resources. When the growth phase slows down, more of the

available resources and energy are allocated to maintain the system (Holling & Gunderson, 2002:34-35).

The conservation phase (*K*) suggests more connectedness, less flexibility and more vulnerability to external events. External stresses force the system to enter the next phase, namely a period of creative destruction which takes place when accumulated capital and structures are released and reach the end phase (Ω) of collapse. The end phase is followed by reorganization (Holling & Gunderson, 2002:43).

The alpha phase (α) emerges when a new system emerges. The trajectory followed in the alpha phase may be similar to the previous path or totally new (Holling, 2001:394; Gunderson, 2009:3-4).

The significance of the repeating adaptive cycle indicates that socio-ecological systems keep to a known sequence to preserve and repeat specific system properties.

Resilience is best expressed by the phases of destruction and reorganization. After a disturbing event, systems reorganize and renew and may flip into an alternative regime, while during growth and conservation slow changing variables predict the system flow. Repeated patterns of rapid reorganization and slow growth after disturbing events are observed in social-ecological systems. The representation of the adaptive cycle in figure 3.3 (Holling, 2001:394) indicates a trajectory that alternates between long periods of slow accumulation and transformation of resources (from r to K) with shorter periods that create opportunities for innovation (from Ω to α).

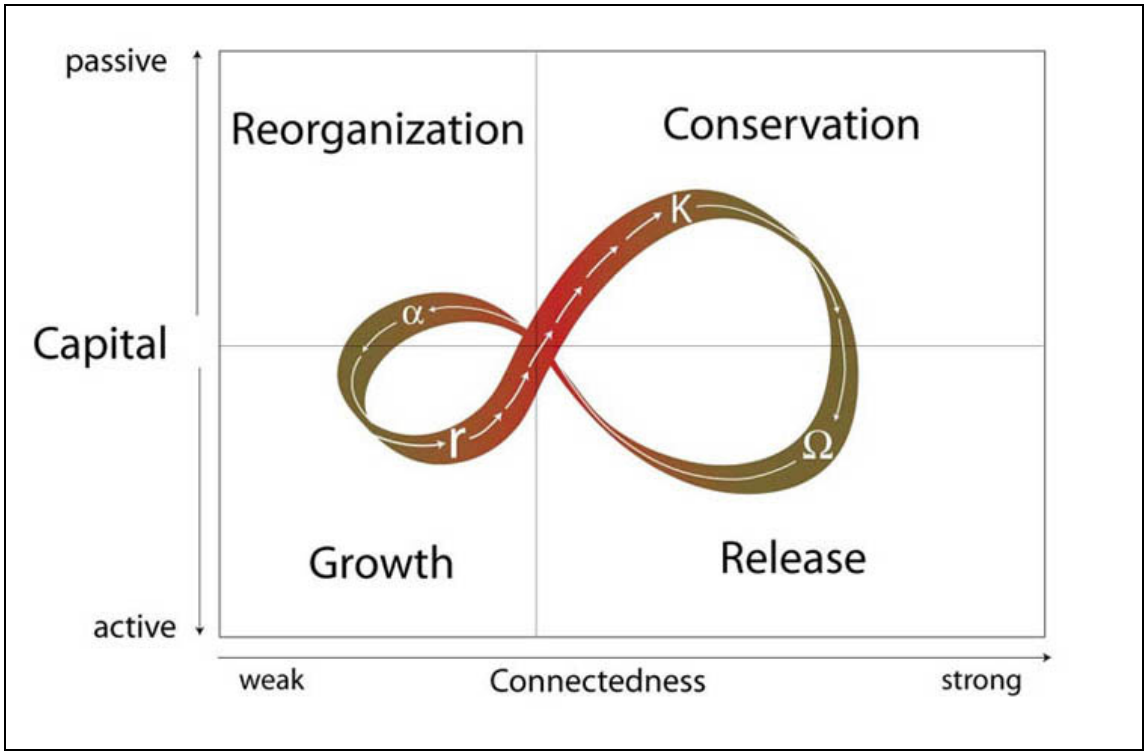


Figure 3.3: The adaptive cycle of a social-ecological system (Holling, 2001:394).

Actions taken in one phase may influence the system on a specific time totally differently than at other times and windows of opportunity may be brief. To have knowledge of systems in different phases of the cycle can inform the type and timing of management interventions (Resilience Alliance, 2010:7).

Holling (2001:393) indicates that three properties shape the adaptive cycle and the future state of a system namely: (a) the inherent potential of a system that is available for change, since this potential determines the range of future available options. This is known as the "wealth" of the system; (b) the internal controllability of a system, indicating the strength of the connection between internal controlling variables and processes; and (c) the adaptive capacity, indicating the resilience of the system, meaning how vulnerable it is to unexpected or unpredictable events.

Holling (2001:394) proposes that potential or wealth implies the number of alternative options available to the system for the future. Connectedness or controllability, determines the degree to which the system can control its own destiny and resilience determines the system's vulnerability to events that can exceed or break control.

Initially, the front loop from r to K becomes progressively more predictable and the back loop from Ω to α is unpredictable and uncertain. The two loops function separately but in sequence, complementing one another. The front loop maximizes production and accumulation that aids with growth and stability and the back loop invention and reorganizing, which leads to change and variety (Holling, 2001:395).

Holling (2001:395) proposes an adaptive cycle where the system's resilience expands and contracts as in figure 3. During the back loop experiments occur and controllability is low and resilience is high (α phase). This weak control helps with the novel reorganization of elements that previously were tightly connected. The high resilience in this phase allows creative experimenting because the system-wide costs of failure are low and internal regulation is weak.

Gunderson (2009:9) supports Holling and sees the α-phase as the post-disturbance period of renewal and recovery. During this phase the social-ecological system is most vulnerable to random and chance events, but multiple opportunities in the form of the so-called "window-of-opportunity" may emerge for the creation of an alternative system. A human-dominated system can develop during this period alternative plans to renew or recover the social-ecological system and the availability of different forms of capital, in the form of natural, social and economic, is of the utmost importance. Remnant and undistorted components in systems that endured the disturbing event, like infrastructure and social relationships, aid renewal and recovery.

Successive adaptive cycles are known as panarchy and is explored in section 3.3.2

3.3.2 Panarchy

Gunderson (2009:4) reports that the word "panarchy" is derived from the Greek god Pan and means "rules of nature". According to Gunderson (2009:4) panarchy is how variables at different scales interact to control the dynamics and trajectories of a social-ecological system. Panarchy is therefore a theory, which suggests that abrupt changes occur as a result of the interaction between slow and broad variables with smaller, faster ones that

follow in rapid succession. There are indications of a top-down approach where slow, broad features control small, fast ones, as well as a bottom-up approach where small events create change in slower, broader features. Gunderson (2009:5) indicates three ingredients for a panarchy namely (a) subsystems of adaptive cycles that represent system dynamics in a specific scale range; (b) dynamic systems that occur at different scale ranges; and (c) coupling of those systems across scales.

The panarchy theoretical model suggests that at key times after disturbing events, cross-scale connections emerge which are critical to system recovery. Succession of adaptive cycles is known as panarchy and indicates the evolving nature of complex adaptive systems (Holling, 2001:396). Panarchy indicates that certain properties, like connectivity, can make a system vulnerable due to the fact that disturbing events can expand across temporal and spatial scales. Panarchy also accentuates the critical importance of interactions with broad, slow variables which are critical for post disturbance recovery and resilience (Gunderson, 2009:13).

Two terms are used to link scales namely: (a) “revolt” that indicates small events that cascades up to larger scales. Thus a “revolt” connection results when a small critical change in the Ω-phase of the first cycle cascades quickly to the larger and slower *K*-phase of the next cycle, where resilience is low. (b) “Remember” is the term used to indicate interaction from the broad to the small scale. This cross-scale interaction creates renewal and recovery of the system. A “remember” connection occurs when a large event in the *K*-phase of a successive cycle causes it to slip back slowly to the α-phase of the previous cycle (Holling, 2001:398; Gunderson, 2009:6). Figure 3.4 represents the successive adaptive cycles of panarchy according to Holling (2001:395).

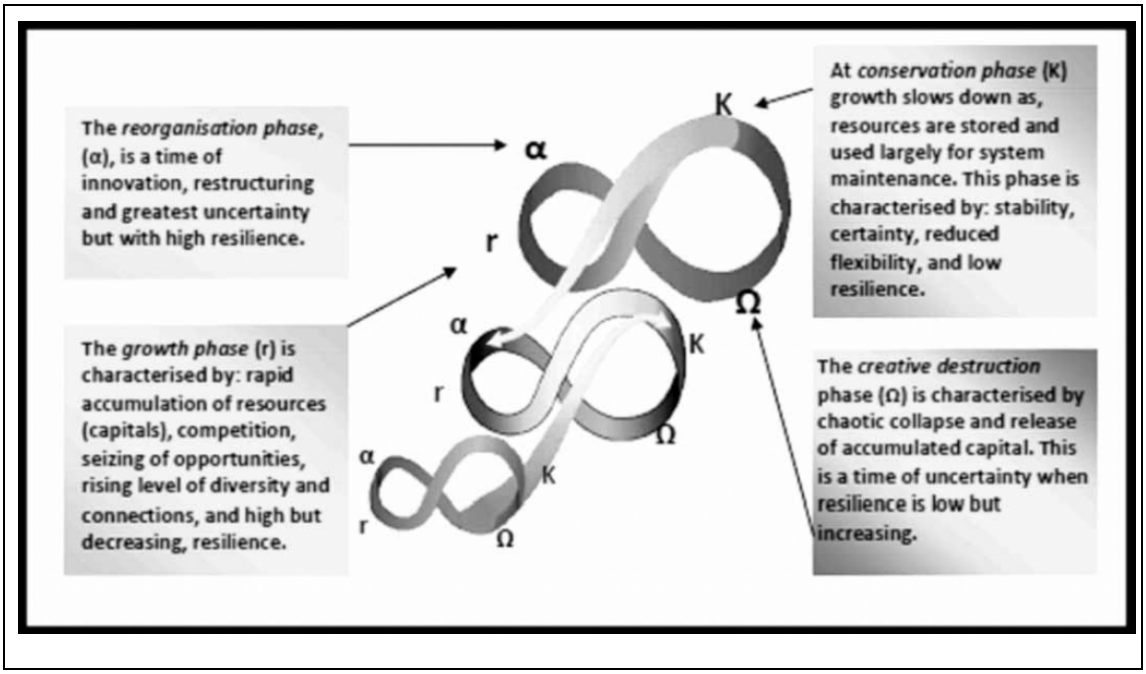


Figure 3.4: Panarchy – successive adaptive cycles (Holling, 2001:395).

Panarchy therefore relies on resilience as an inter-active, dynamic property of a social-ecological system to aid the system to slip back into a known terrain after a disturbing event by means of the cross-scale link of "remember" or to react after a disturbing event by moving upwards into a safe space of maintenance (K-phase) during the revolt cross-scale action.

This research study aims to find the position of the social-ecological system at NWU (Vaal) being studied in the adaptive cycle. The position of the social-ecological system in a specific phase in the adaptive cycle aids to predict possible movement of the social-ecological system into a new phase and may aid with management decisions and problem solving regarding social-ecological matters.

In the next section the resilience assessment approach, which builds on the concepts resilience, adaptive cycle and panarchy, is discussed.

3.4 THE RESILIENCE ASSESSMENT APPROACH

3.4.1 What is meant by the resilience approach?

Holling and Meffe (1996:334) indicate that environmental management should facilitate existing processes and variables, rather than changing and controlling them. Facilitation in a social-ecological system maintains

ecosystem resilience and maintains the organizing processes and structures, serving the long term interest of humanity and the natural functions and species diversity of the ecosystem. The preferred line of approach is therefore to adopt a conservative approach to changing parameters of a system. The maintenance of the natural state is preferred rather than resorting to the manipulation of system components or dynamics.

The resilience assessment approach consists of strategic questions and activities which guide the researcher to construct a conceptual model of a social-ecological system of a place of interest. Take into account available resources, stakeholders and governance issues of the social-ecological system potential thresholds which can indicate a breakpoint between alternative systems which are identified, as well as factors contributing to or eroding resilience. The resilience assessment aims to provide information for strategies to aid the social-ecological system in order to cope with known and unexpected change (Resilience Alliance, 2010:4).

Directed by alternative thinking about and practicing of natural resource management, the resilience assessment approach built on research insights from complex adaptive systems and integrates a set of key concepts. The resilience assessment approach assumes the natural-resource context to be complex and focuses on sustainable, long-term environmental benefits for both the environment and human beings (Resilience Alliance, 2010:4).

Due to the limits of forecasting, Walker *et al*. (2002) support The Resilience Alliance and indicate that the focus must be on learning to live within systems, instead of controlling systems. The focus is here on maintaining the capacity of the system to cope with whatever the future brings, without the system changing in undesirable ways, therefore maintaining or increasing a system's resilience. According to Walker *et al*. (2002) the goal of resilience management is to discover the points of intervention in a social-ecological system where resilience can be increased for future and unforeseen changes.

Walker *et al*. (2002) indicate that a resilience-centred approach is based on the following assumptions namely: it aims to identify and understand processes responsible for the creation of thresholds in a social-ecological

system; the need to proceed despite uncertainties in variables in a social-ecological system; decisions are made with imperfect knowledge and with limited resources regarding all sub systems of a social-ecological system; market-based valuations of the social-ecological system is distorted and imperfect; role players in a social-ecological system have their own preferences regarding outcomes and processes; and well-defined property rights do not exist for many ecological goods and services. Therefore, there are no markets available to value these goods and services.

This research study, which use the resilience assessment approach, is a new approach to assessment of social-ecological systems at a university campus and therefore fills a gap in the current understanding of the application value of the approach.

The resilience assessment approach was used in various studies worldwide as reported in section 3.4.2.

3.4.2 Examples of research studies, which used the resilience assessment approach

Walker *et al.,* (2009) used the workbooks of the Resilience Alliance in a study of the Goulburn-Broken region in Australia and indicated that this approach treats biophysical, social and economic elements as components of a single social-ecological system. The capacity of the social-ecological system continues to deliver goods and services to people and the trade-offs associated with different regime shifts are emphasised by the approach. The researcher indicates the region as a system by defining the key sub systems, identifying the main issues and drivers and potential events that include change in drivers. The capacity of the system to deal with the events based on the major benefits generated by the region and the biophysical, economic and social sub-system that underpin the continued supply, were mentioned. The resilience of the region was then assessed by examining past changes in resilience and the use of the adaptive cycle of Holling and Gunderson (2002:25-62) to interpret the pattern of change. Two components of resilience were assessed, namely: (a) specified resilience, considered valuable to the region to identify stresses and changes, as well as threshold effects to control

variables, their interaction and attributes that determine thresholds; and (b) general resilience that identifies attributes in the Goulburn-Broken system and the general capacity to cope with events (Walker *et al*., 2009).

The website of the Resilience Alliance reports on fifteen social-ecological system case studies over a wide time span and includes the Causse Mejan in France; the Coral Reefs of the Caribbean; the Spiny Forest in Southern Madagascar; the Everglades in Florida, USA; the Gorongosa National Park, Mozambique; the Goulbourn-broken Catchment, Australia; KristianstadsVattenrike in Sweden; the Mae Ping River Basin, Thailand; Maine Fisheries, USA; the Malinau Region in Borneo; the Northern Highland Lakes District, Wisconsin, USA; Phoenix, Arisona, USA; the Rangelands of New South Wales, Australia; the South-east Lowveld, Zimbabwe; and the Western Australian Wheatbelt in Australia (Resilience Alliance website, 2013).

Regarding NWU (Vaal) the resilience assessment approach (2010), and the framework for studying a social-ecological system (Du Plessis, 2008), contributes to the construction of a conceptual model of the social-ecological system of NWU (Vaal). The history of the campus and region are taken into account to detect possible repeating patterns in the system and sources that enhance or erode resilience in the social-ecological system. By accepting the real situation regarding the social-ecological system of NWU (Vaal), the approach is applied to aid the campus and its inhabitants over the long-term.

The next section clarifies the concept of social-ecological system.

3.5 THE CONCEPT SOCIAL-ECOLOGICAL SYSTEM (SES)

The concept of social-ecological systems evolves with increased scientific and experiential awareness regarding the interdependence between human society and the natural environment. Various frameworks were proposed for the studying of a social-ecological system. Earlier views indicate a social-ecological system as a separate or overlapping system of natural and human systems with linked activities (Du Plessis, 2008:65). Later views see a social-ecological system as a dynamic, integrated living systems consisting of agents (human and other), their actions and behavioural patterns interacting in a physical environment (chemicals, water and energy).

Du Plessis (2008:65 - 67) reports four propositions of social-ecological system namely:

A social-ecological system is a single integrated system that spans across matter, life and mind, thereby incorporating human, social and cultural phenomena. Each system is unique in respect of boundaries and relationships. The interest of the researcher, or a local issue, directs the identification of elements and aids to simplify the system model. A system needs to be understood in the context of cross scale linkages with systems higher and lower from the focal scale and relationships between elements of a number of scales.

A social-ecological system consists of relationships between elements at various scales accommodated in nested arrangements. Three system aspects that are relevant include: (i) the cross-scale linkages between entities; (ii) how the system reacts as determined by physical, social and mental processes that drive the system's dynamics and governors that regulate the dynamics; and (iii) the nature of the relationships in the system as influenced by key variables such as resilience and adaptability (Du Plessis, 2008:66).

A social-ecological system differs from pure ecological systems in the introduction of abstract thought and symbolic construction as drivers of change processes and as governors of behaviour.

A social-ecological system is complex and adaptive with properties of self-organization and emergence.

Du Plessis (2008:67) elaborates by indicating that a study of a social-ecological system needs to be rooted in a suitable systems approach like the resilience assessment approach. The system needs to be defined and mapped in terms of its dynamics. The identification of main entities, links between entities, cross-scale structures and aspects which determine behaviour and dynamics are essential. Social-ecological systems are studied to improve understanding and aid decision-making and problem solving regarding system management. Understanding attributes that influence how the system deals with change and also the likelihood of successful interventions to promote sustainability are high on the priority list. The

research objective is therefore determined by the specific attribute, in this case resilience.

3.5.1 More views on social-ecological systems

A social-ecological system is defined by Anderies *et al*. (2004) as an ecological system intimately linked and affected by one or more social system. Both ecological and social systems contain units that interact interdependently and may contain interactive sub-systems as well. Anderies *et al.* (2004) uses a social-ecological system to indicate interdependent relationships between humans interacting with biophysical and non-human biological elements. Du Plessis (2008:69) reports that the view of Anderies *et al.* (2004) presents an anthropocentric worldview on social-ecological systems because it is either seen as a system of humans affecting nature or nature providing a service to humans.

Folke *et al*. (2002:438) indicate that a social-ecological system constantly changes. Ecosystems can respond to change in a smooth way or with drastic shifts. The prediction of drastic shifts is inaccurate and can seldom be done in advance.

The Resilience Alliance (2010:6) views social-ecological systems as holistic because it does not focus on a detailed understanding of the parts, but on how key components contribute to the dynamics of the whole system. A social-ecological system responds to changes sometimes by triggering so-called feedbacks that may amplify change in the whole system or stabilize it. The properties of social-ecological systems include self-organizing by adjusting through interactions; novel configurations and adaptation to disturbances.

Du Plessis (2008:70) reports that the view of The Resilience Alliance (2010) can be seen as an eco-centric interpretation of social-ecological systems. Humans are therefore merely another species fundamentally interdependent and co-evolving with the biotic community and abiotic environment.

Du Plessis (2008:70) affirms that both the anthropocentric and eco-centric interpretation lack the third dimension of symbolic construction. Both social and ecosystems share the dimensions of time and space. Humans are

positioned in nature as an integral part of the processes of change and co-evolution. At the exterior level, humans and their constructions are an indivisible part of the biosphere and they, like any other organism, participate and co-create the metabolic and change processes that shape the biosphere. Humans are bound by the same laws that apply to nature. The interior processes of humans allow them to apply these laws to create and adopt technologies that can operate outside the laws of the biosphere. The incorporation of the interior aspect of a social-ecological system allows for novelty, foresight, reflection and learning.

This view of Du Plessis, is supported by Gunderson (2009:11), who indicates that resilience management must include a learning based approach, which allows for accumulation and periodic testing of knowledge. Two forms of learning are evident namely episodic and transformational learning. Episodic learning takes place when previous models are no longer relevant and experiments are done to create new policies or approaches to solve problems. Transformational learning uses cross-scale surprises and novel solutions to solve problems by identifying domains which includes several levels of panarchy.

It can be concluded that episodic learning results in a set of new policies and plans in response to previous actions which did not deliver the desired results and transformational learning uses available information and the situation as it is to produce workable solutions. The resilience assessment approach is focused on transformational learning, therefore solving problems by using what is available in a social-ecological system at the specific time.

A social-ecological system is therefore a complex, adaptive system with the ability to indicate degrees of change and uncertainty. Du Plessis (2008:83) concludes that any modelled system of a social-ecological system needs to account for interaction between interior aspects, like value systems or regulations, and interior changes like a shift towards a specific value system. It must also indicate the flows between interior events on exterior change and closes the loop, accounting for exterior changes by the manifestation of interior events. Assessment processes that only measure indicators quantitatively are inadequate for a social-ecological system and the

development of indicators that can monitor changes in both the bio- and noospheres are a necessity.

The view of Du Plessis (2008) therefore incorporates both interior and exterior events in a social-ecological system, the possibility to predict possible levels of change and uncertainty exists. This will enable planning and reflection on actions taking in a social-ecological system and enable preparedness for possible future events. Gallopin (2006:294) supports this view of du Plessis and indicates that the need to investigate the complete social-ecological system arises from the increasingly recognized evidence that understanding and anticipating the behaviour of all relevant components indicates that social-ecological systems are non-decomposable systems.

For this research study, it implies that after assessing the social-ecological system with the resilience assessment approach, reflection, thought and understanding need to guide the structuring of management practices. The latter processes will aid to incorporate all dimensions of the social-ecological system and advance the system in total, not only environmentally, economically or socially.

In the next section the history of the NWU (Vaal) is revealed. Information in this section helped with the construction of a historical timeline over four decades in Chapter 4. The timeline revealed possible disturbances which enhances or degrades the resilience of the social-ecological system researched.

3.6 HISTORY OF THE FOCAL SYSTEM

3.6.1 Beginning of the NWU (Vaal) – the focal system

The NWU (Vaal) was established in 2004 as part of the North West University (NWU). The North West University consists of three campuses based in Potchefstroom, Mafikeng and Vanderbijlpark. The Institutional Office in Potchefstroom co-ordinates university-wide actions while all three campuses operate separately with its own rector and management team.

The NWU (Vaal) is the smallest of the three NWU campuses and is based in the Vaal Triangle which is a highly industrial area. The Vaal Campus has a multi-racial staff and student population.

The NWU (Vaal) was established due to popular demand from nearby business and industries in the Vaal Triangle. In 1963, then the Potchefstroom University for Higher Education (PU for CHE), presented refresher courses for cost accounts in Vanderbijlpark on request. This was seen as a satellite campus and three years later, lecturers from Potchefstroom started presenting a part time B Comm. degree, followed in 1970 with a BA degree in Vanderbijlpark in temporary buildings. The increase in student numbers resulted in a permanent office for the PU for CHE in 1973. During 1973 the PU for CHE bought 88 ha of land along the Vaal River for the purpose of a campus. In 1976 part-time lectures commenced with a B Sc degree and the first 3 permanent professors were transferred to Vanderbijlpark. Full-time lectures commenced in January 1977 with 6 permanent lecturers for 52 students. In 1978 the academic offerings included a B Ed degree and a Higher Education Diploma. In this year, special permission granted from the local municipality, set the bought land free of normal procedure for the starting of a town and in 1980 a zoning plan was set for a recreational hall, rugby field and parking area. The municipality of Vanderbijlpark wanted a full development plan of the campus before consent was given to start with building procedures. This master plan incorporated the academic policy as well as the nature and character of the university campus. In the final zoning plan provision was made for a five phase development action on the campus which could accommodate 10 000 students (De Klerk & Moller, 2005:478).

In 1983 the campus was officially named the Vaal Triangle Campus with a vice-rector in charge. Construction of the riverside campus began in 1981 to 1982. In 1981 the first professors in the Faculty of Engineering were appointed. In 1984 student numbers increased to 1140 and the first graduation ceremony with 99 graduates was held. In 1985 the first two men's residence were occupied and within two years 185 students were accommodated in these residences. In 1992 a decline in student number from 1900 to 1500 occurred. This was due to the moving of the Engineering

faculty from Vanderbijlpark to Potchefstroom. In 1990 a nature reserve was started on the campus when six springbok (*Antidorcas marsupialis*) and six blesbok (*Damaliscus pygargus*) were introduced to the campus area. Species like zebra (*Equus greyvi*) and ostriches (*Strutjio camelus*) were later introduced. A variety of man-made dams were added and trees were planted on campus during this time (De Klerk & Moller, 2005: 478).

English was introduced as an additional medium of instruction making the campus more community-oriented. 1994 revealed wide-ranging transformation on campus by the introduction of a four year B Comm. degree to aid students from disadvantaged communities as well as the first fully democratic elected Student Representative Council.

The incorporation of Vista University of Sebokeng in 2002 lead to student numbers exceeding 2000 for the first time during 2003 when 2247 students were registered. This incorporation of a previous disadvantaged university set the Vaal Campus on a more autonomous road and also indicated the influx of government money to add facilities. In 2004 the campuses of Potchefstroom, Mafikeng and Vanderbijlpark merged and the student numbers increased to 3038 at the NWU (Vaal). The biodiversity on campus increased to 130 springbuck, 35 bles buck, 15 oryx and 12 black wildebeest as well as duikers and a lot of geese. A new development plan was set and it was proposed to focus activities on the north western part of the area (De Klerk & Moller, 2005:481).

3.6.2 Governance in the social-ecological system

3.6.2.1 University

On 2 January 2004 the PU for CHE and NWU (Mafikeng) embarked on a merger with the satellite campus in Vanderbiljpark. Acceptance of this merger was based on political enforcement. Hurdles during the merger were resistance to change and a low level of trust between members of different universities. A unitary but multi-campus model with an institutional head was proposed. That implied one council and senate with one vice-chancellor and one set of values, policies and procedures. The institutional office based in Potchefstroom acts as the horizontal “glue” to integrate and coordinate across

campuses. “Do” values in the form of integrity, commitment, accountability and respect were proposed (Eloff, 2007).

The alignment of academic programmes across various campuses strived to achieve a quality process where a degree at any NWU campus will have the same standing. Challenges which are permanent features of a multi-campus university include long distances between campuses, cost and time spent on travelling, roads in poor conditions and the danger of driving at night (Eloff, 2007).

The Vaal Campus incorporated all the staff from the Sebokeng Campus of Vista University and all pipeline students were given the opportunity to complete their academic programmes.

Fiscal discipline during the merger, with assistance of the Department of Education, aided the merger process. A system of performance agreement implemented for all academic staff and managers aided to prevent tension in management positions. An integrated administrative system for all students was established, as well as the establishment of an invigorated student culture on each campus through sport and cultural activities. The merger aimed for better management, resource access, new found acceptance and legitimacy in higher education, with new buildings and growth. The NWU is known as a highly competitive, globally recognized, innovative, quality teaching- learning and research institute (Eloff, 2007).

3.6.2.2 The Vaal River Barrage

The Vaal River extends over a distance of 1300 km and is labelled by international standards as a medium-sized water way. Being a tributary to the Orange River, it flows from the water rich Drakensberg to the Atlantic Ocean. The NWU (Vaal Campus) is situated in the Vaal River Barrage catchment area which covers a surface area of about 900 km^2 in a most densely populated area of 10 million people who reside there, with 13 600 wet industries, 20 waste water treatment plants and a number of mines (Tempelhoff *et al*., 2007:110). Flooding in 1917, 1919 and 1974-1975 along the Vaal River determined the 100 year flood line which is still relevant up to the present.

In the 1960's when lecturing classes started at Vanderbijlpark, one of the most severe droughts of the century wreaked havoc in many parts of the country. This situation placed considerable pressure on the catchment. Strategies of water restrictions secured success over the short term, but an increased demand for water in the future was indicated. The need for water in the industrial sector reached its highest point and in 1973 the first fuel crisis initiated the government to launch the Tukhela transfer scheme. During the 1980s the demand for water increased with the longest drought in the 20th century in the Gauteng region. Comprehensive measures were introduced to find additional water resources, but limited attention was given to the recycling of water (Tempelhoff, *et al.,* 2007:116).

During the 1980s there was increasing evidence of waste water pollution in the Vaal River Barrage. Extreme pressure from the government on industries, to supply ammunition for the so-called "Border War" in Namibia, left little concern for environmental related matters. The informal 'upliftment' of urban influx control by the government saw an increase of people flocking to cities which resulted in illegal squatting on open land areas, and therefore the establishment of informal housing settlements in the catchment areas of the Klip – and Suikerbosrand Rivers which both tribute to the Vaal River Barrage catchment (Tempelhoff, *et al.,* 2007:118).

The first democratic election of 1994 saw industries in the Vaal Triangle collapse into a phase of post-industrial lethargy and major privatization programmes were initiated. Unemployment of unskilled workers was in the order of the day and lead to the prediction that up to 60 % of the regions inhabitants will be without work in 2015. Civil society, in conjunction with government, pressurized industries to reduce air and water pollution. Whistle blowers made disclosures of ground water pollution in affected areas (Tempelhoff, *et al.,* 2007: 117).

During this time there was also a rapid changeover in the structure of municipal services due to the new democratic dispensation, which lead to losses in valuable human resources and technical experience. In 1992, 6105 sewer blockages were reported in the Vaal Barrage River catchment. 1996

also saw the establishment of the first catchment management forum in the Upper Vaal and flooding of the Vaal River occurred again.

The four catchments of the Upper Vaal, Blesbokspruit River; the Klip River (home to Witwatersrand Gold mines and urban Johannesburg); the Rietspruit River (Iscor / Mittal as major industry) and the Leeu-Taai River (home to SASOL - South Africa Synthetic Oil Liquid chemicals and other industries) as well as the release from the Vaal Dam determine the water quality of the Barrage.

Rand Water was responsible for all water monitoring up to the passing of the National Water Act (NWA) 36 of 1998. This act turned ownership of water to the South African people, held in custodianship by the state in the form of the Department of Water Affairs and Forestry (DWAF). Today Rand Water still performs the monitoring of water on conditions which the forums have established for quality. Forums propose monitoring of phosphates, ammonia, nitrates and faecal coliform to indicate pollution from sewage; sulphates, chlorides, heavy metals and acidity indicate acid mine pollution; fluorides, chemical oxygen and other indicators indicate industrial pollution and the last monitoring is done on water fleas and guppies (fish) (Tempelhoff, *et al.,* 2007:120). The “polluter pays” principle was introduced but could only work if and when polluters attend forums. However, attendance is voluntarily and self-regulation the norm in practice.

Sebokeng is a township neighbouring Vanderbijlpark. Like most townships, the influx of people who built shacks put an increased demand on the use of water and sanitation. The area is overcrowded in infrastructure which is old and not maintained. Open storm water drainage and sewage pipes going straight into storm water drainage and from there directly into the Rietspruit River and Vaal River are common sites. People living in the vicinity of the rivers are exposed to unpleasant smells, stomach problems, lots of dead fish in the river and algae flourishes (Vaal Environmental Community News, 2013).

Flooding of the Vaal River in 2006, 2010 and 2011 increased health and environmental risks related to the previous mentioned problematic scenarios.

The Vaal Environment Justice Alliance received training on The Promotion of Access to Information Act (PAIA, 2000) which provides that access to information from industries must be granted to the community. Stakeholders may ask from companies Environmental Master Plans, Water use licenses, and Mining Right Permits/Licenses. Industries like Arcelor Mittal denied information in 1996, as well as the Department of Water Affairs (DWA), based on the fact that they were not custodians of the information. Arcelor Mittal is seen as the 4th highest carbon dioxide emitter in South Africa. In 2012 SASOL (South African Synthetic Oil Liquid) provided 4 months of water monitoring results, copies of water permits and exemptions in terms of the old Water Act (1956). Omnia, as well as Anglo Coal, refused to make documents available claiming that they need to protect commercial information of a third party and private body (Vaal Environmental Community News, 2012).

The Minister of Water Affairs reported in 2012 that 8252 properties irrigate from the entire Vaal River System: 1202 properties were unlawful users; 1361 properties completed verification applications and verifications for 3927 properties were not started yet; validation was in progress for 1894 properties and completed for 6900 properties. The biggest problem was the water quality in the Vaal River due to untreated sewage from non-functioning municipal water treatment works, industrial effluents, acid main drainage and other activities along the Vaal (Vaal Environmental Community News, 2012).

The people living in Steel Valley, near Arcelor Mittal between Vereeniging and Vanderbijlpark, started a Steel Valley Crisis Committee after the death of many animals. Groundwater pollution related to 10 big unlined evaporation dams, a 125 slack dam, as well as a cannel running from the steel mill through the farming area into the Vaal River were blamed for the disaster. Most of the residents moved out of the area since 2004 and in 2008 only 10 families were left. People coming from this area died mostly from kidney failure and cancer. They also need to keep indoors due to dust and air pollution from the slack dam (Vaal Environmental Community News, 2012).

Recently residents reported personal trauma as their quality of life along the Vaal River is deteriorating. The demand for restoration of the Vaal River Barrage to encourage leisure activities are increasing. In January 2006, after

heavy rain, sediment churning due to the opening of sluice gates and the discharge of untreated waste water resulted in fish deaths lower down the river. Anglers were upset by the large number of deaths of indigenous and endangered yellow fish (Tempelhoff, *et al.*, 2007:125).

The large amount of sewage pumps (50) which were pumping waste water into the Barrage, as well as equipment failing and the producing of inferior effluent, with limited budget allocations and poor work ethics of workers at sewage waste treatment plants aided the disaster of 2006. Later in July 2006 more fish deaths were caused by run-off water from chemical industries (Tempelhoff, *et al*., 2007:125).

3.6.2.3 Link in governance of upper and focal system

Regarding the NWU (Vaal Campus) river water is used to fill the man-made dams on campus. These dams are used to irrigate gardens, serve as a recreational spot for students sitting next to it and are also used for the subsistence of fish, which were placed in the dams. Fish from the dams are caught and released to detect pollution in and the quality of the water. The Vaal Campus is also home to a canoeing club which uses the river for practice sessions. Sewage or industrial spills in the river resulted in no exercise for members of the canoeing club, and often bad smells of river water and waste drifting in the water proved to be evidence of different forms of water pollution (Scholtz, 2013)

In order to find the patterns in the behaviour of the social-ecological system of the NWU (Vaal) a time line was set to indicate relevant occurrence in the system itself, as well as in the upper scale system of the Vaal Barrage catchment. The timeline produced valuable insight in the big picture of the social-ecological system and aided to establish the position of the social-ecological system regarding resilience in action. The timeline is revealed in chapter 4 which discusses the findings after applying the resilience assessment approach on the social-ecological system of NWU (Vaal).

3.7 THE LEGAL COMPLIANCE AUDIT OF 2012

In 2012 a legal compliance audit was performed on the NWU (Vaal) by the Centre for Environmental Management of the NWU (Potchefstroom). The audit revealed 17 legal non-compliances which include: 10 findings regarding the management of hazardous substances and dangerous goods; 2 findings related to general waste management; 1 finding on the management of building waste; 1 finding on the use of water and water management, and 5 findings regarding biodiversity and land management (NWU, 2012:6).

According to the legal compliance audit two key activities at risk were the management of hazardous substances and dangerous goods and the land and biodiversity management. The lack of arrangements to store hazardous and dangerous goods, the lack of training and operational documentation, the containment of spills and management and disposal of hazardous waste raised concerns (NWU, 2012:6).

The lack of formal arrangements and reliable screening routines put general waste management, building waste management and water use also at risk. The lack of arrangements regarding the generation, re-use, reduction and recycling of waste as well as disposal of general and hazardous waste like the mixing of waste streams and illegal disposal does not adhere to legislative requirements (NWU, 2012:7).

Land and biodiversity management were criticised for the management of protected, alien and invasive species; the keeping of game and the management of potential natural fire risks.

These findings of the legal compliance audit were taken into account when collecting data and the expectation is that attempts are made to solve some of the legislative non-compliance issues.

3.8 SUMMARY OF CHAPTER 3

In Chapter 3, resilience is defined according to the definition of Holling (1973) as the capacity of a system to persist within a domain in the face of change and is therefore a measure of the ability of the system to absorb changes of different variables (*cf.* 3.2). The adaptive cycle, which indicates change of a

social-ecological system over time, aids to inform about the current position of a system in the cycle and can help to predict possible progression of the system in the cycle (*cf.* 3.3). The resilience assessment approach that aids to construct a conceptual model of a social-ecological system of a place of interest, take into account associated resources, stakeholders and real issues to aid management in the long term (*cf.* 3.4). The complex nature of a social-ecological system requires not only quantitative indicators of the status of a social-ecological system, but requires reflective thinking (*cf.* 3.5). A social-ecological system is ever dynamic and never in a stable state, but constantly changing therefore challenging the resilience of the system. The human ability of thought and reflection enables the management of social-ecological systems and increase the possibility to solve problems, to predict incidents and maintain resilience. The history of the NWU (Vaal) and immediate region revealed relevant information for the setting of a historical timeline in Chapter 4. A legal compliance audit, performed in 2012, revealed legislative non-compliance issues. In Chapter 4 the results of the research are discussed.

CHAPTER 4

RESULTS

4.1 INTRODUCTION

Chapter 4 reveals the results from data collected via the literature and document reviews, interviews and observations as well as the resilience assessment approach. The resilience assessment approach directs the flow and sequence of reporting. In this chapter the natural resources disturbances, thresholds and interaction across scales were identified to aid with the construction of a historical timeline of the social-ecological system being studied. Governance and social networks are indicated and taken into account to aid with the structuring of a conceptual model which indicates the relation between external control, slow - and fast changing attributes and governance of the focal system.

4.2 THE FOCAL SYSTEM

4.2.1 Defining the focal system

The NWU (Vaal) is situated along a 3 km range of the Vaal Barrage catchment. The NWU (Vaal) is also a nature reserve and host a variety of animal and plant species. A rapid increase in student numbers in the last five years, called for more lecturing halls, a new library and more available sport and recreational sites.

A limited amount of hostels is available on campus to host students. The amount of students staying in hostels on campus currently amounts to 445. Most of the students are day visitors, coming to the campus via bus, taxi and car (Venter, 2013). The use of energy and water is especially high during day time, and decreases at night time although evening lectures proceeds until 22h00.

Being part of the Vaal Barrage Catchment has advantages in the form of beautiful recreational facilities next to the river, quiet spots where students can relax and participation in water sports like canoeing. Disadvantages include

raw sewage and industrial release, which is spilled into the river upstream, causing bad smelling water, pollution and fish deaths, high counting bacteria growth and algae blooms flourishes.

Being part of an industrial town and region, the campus is in the vicinity of the nearby steel industry Arcelor Mittal and across the river, South Africa Synthetic Oil Liquid (SASOL) as well as the Electricity Supply Commission (ESKOM) power station known as Lethabo. All of these industries use water in manufacturing and release CO_2 and other gaseous substances in the air. Rand Water in Vereeniging, releases lime residue in the Vaal River as part of the water purification process (Randwater, 2014; Tempelhoff, 2013).

The main environmental issues of concern and their valued attributes which were identified after the interviewing of various stakeholders and observations by the researcher are summarized in table 4.1.

Table 4.1: Summary of the main issues of concern and the valued attributes of the system.

Issue number	Main issue of concern for assessment	Valued attributes of the system
1	Waste generation	Opportunity to train students on recycling and reducing of waste
2	Land use, available land and land degradation.	Richness in biodiversity; aesthetical enhancing to relieve stress and promote wellbeing; sport fields aid with exercise and health
3	Biodiversity	Aesthetical enhancing to relieve stress and promote wellbeing; an example of a symbiotic relationship where human wellbeing is connected to nature
4	Pollution – water, soil and air due to hazardous waste; building activities and general waste	Awareness and activism from students can promote social responsibility

Issue number	Main issue of concern for assessment	Valued attributes of the system
5	Energy use	Awareness of excessive energy use can promote responsible social behaviour; participation in events like Earth hour and competition between hostels for lowest usage

4.2.2 Key natural resources and ecosystem services

The following key natural resources and ecosystem services were established during the resilience assessment approach namely: water; soil; air and biodiversity

Water is used for recreation (canoeing, boating; man-made dams - fishing); economic (to irrigate university gardens); for conservation of plant and animal species on campus. Water is subsistent used for hygiene and health of humans.

Soil is economical and subsistence used to construct buildings; recreational in the form of sport fields; for conservation as the home of animals and plants; and also has a cultural use as a nature reserve.

Air is subsistence used to support life of plants, animals and humans; economically used in air conditioned lecture rooms and offices.

Biodiversity in the form of plants and grass provides nutrition for a variety of animal species like birds and wildlife. The following is also services provided by plants: the provision of wildlife habitat to a variety of animal and plant species; safe hiding/habitat provided by plants for animals; carbon storage by the invader eucalyptus wood and other plants; human wellbeing is promoted by the aesthetic environment; recreational opportunities for various type of sport on sport fields.

4.2.3 Disturbances

The use of the resilience assessment approach revealed the following disturbances in the focal system as summarized in Table 4.2.

Table 4.2: Summary of focal system disturbances and their attributes

Disturbance Past/present	Pulse/press	Frequency of occurrences	Recovery time between occurrences	Components most affected	Magnitude of impact – minor/ severe	Any change in past years or decades
Building	Press	Yearly/ biannually	Limited	Soil Also water, air	Severe	More intense after 1996
Drought	Press	Every 20/30 years	Getting less	Soil, water, biodiversity	Severe	More intense – global warming
Flooding	Press	First every 20 years, more frequent – yearly or 5 yearly	Getting less	Water and soil; biodiversity	Severe	More intense- global warming; fish deaths and pollution
Waste	Press	Daily	None	Soil, water, biodiversity	Severe	More intense due to more people
Future						
Drought /flooding	Press	Increased frequency	Cannot predict	Water, soil and biodiversity	Severe	Will be more intense
Waste	Press	daily	None	Soil, water, biodiversity	Severe	More intense due to more people

From Table 4.2 the following three press disturbances have currently the most significant effects on the focal system namely:

New buildings have a severe impact on the immediate environment and activities intensified after 1996. Comparing the campus plan before and after 2010 indicates the effect of new buildings on available land. Meyer (2013) reported that visible evidence of the effect of more buildings on biodiversity is seen in the decrease in numbers of terrestrial animals like meercats, lizards and even the domestic campus cat. These small animals were visible in open areas between buildings, and disappeared when building activities increased. The built of new building affect soil, water and air.

Climate change is made visible by the frequent and unpredicted occurrence of flooding and drought. The hundred year flood line of the Vaal River, one of the borders of the campus, was established between 1917 and 1919. 33 ha of available land on the NWU (Vaal) is below the flood line (Du Plessis, 2013). Floods occurred on campus in 1974, 1975, 1996, 2006, 2010 and 2011. The last flood of 2011 raised the river level above average to about 6 m. The lapas and all gardens near the river, as well as rugby fields below the flood line were under water. This drastic increase in the height reached by the flooding river raised concern about the effects of climate change. The photographs in Figure 4.1 indicate the effects of the 2011 flood on the NWU (Vaal) campus.

Figure 4.1: Photographs of the flood of 2011 at the NWU (Vaal) (Strauss, 2011).

Serious and severe drought conditions occurred in the region in from 1964 to 1970, 1982, 1984 and 1986-1988, 1991 to 1995, from 2002 to 2005, and in 2013. A deficit of 20 – 25 % of normal rainfall patterns is seen as drought. Low rainfall patterns are synonymous with cloud-free skies and high temperatures which stress plants and deplete surface-water reserves through evaporation (SA Weather Service, 2013).

The impact of drought on the NWU (Vaal) placed an increased demand on management to feed the wild life (Scholtz, 2013). Due to crop failure in the rest of the region, food prices increase which affect the students economically. Possible veld fires which may destroy grazing areas of wild life quickly and have the possibility to destroy buildings, without suitable safety and action procedure by Protection Services of NWU (Vaal) make the impact of drought serious (NWU, 2012).

Van Wyk (2013) reported that the average surface temperature of the earth has already risen by 1 °C since 1900, and since 1989 the hottest 12 years in the last 150 years were indicated. South Africa constitutes only 0,67 % of the world's population, but is the 19th highest emitter of greenhouse gases and responsible for 1,2 % of global emissions. When emissions are worked out

per gross domestic product (GDP) output, South Africa's ranking jumps to the 7th place. Increased greenhouse gas emissions lead to water shortages influencing precipitation patterns and groundwater table. Ecosystems become vulnerable and severe droughts occurred annually. According to van Wyk (2013) is the occurrence of extreme rainfall in the form of floods responsible for erosion of soil and more suspended solids and toxins in overload sewage systems. Climate change also result in rising temperatures in water resources, which decrease the oxygen levels and release phosphorus from sediments. Algae and bacteria flourish in higher water temperature, which cause health risks by mobilizing pathogens.

Engelbrecht (2010:130) supports the notions of van Wyk and indicates an average increase in temperature of 1,4 °C per century in South Africa. The Intergovernmental Panel on Climate Change (IPCC) projected that Africa's regional warming is likely to be greater than the global annual mean warming. Predictions made by future 30 year simulations in weather patterns indicate that South Africa will become drier and intense thunderstorms will occur more frequently over the Gauteng Highveld (Engelbrecht, 2010:137).

The **production of more waste** in the focal system, due to an increase in human numbers as well as activities that generate waste is also a concern for current and future scenario. Waste increases result in pollution of water, air and soil and therefore is an issue of concern to management and environmentally (Basson, 2013). Nkosi *et al*.(2013:9) report that 42 million m^3 of general waste is generated per year in South Africa, with the Gauteng province contributing to 42% of this total. The average amount of waste generated per person per day in South Africa is 0,9 kg. This amount agrees with the averages produced in developed countries like the United Kingdom (UK) (0,73 kg) and Singapore (0,87 kg). By doing a quick calculation it reveals that the 445 permanent residents of hostels on campus generate 400,5 kg of general waste per day and in an academic year of about 250 days 10 0125 kg of general waste is generated.

Waste generated at the NWU (Vaal) can be classified as general waste from an institutional source. Types of waste include: food wastes, paper, plastics, textiles, cardboard waste, wood, glass, ashes, special waste in the form of

consumer electronics, batteries and household hazardous waste as a result of food services, students staying in hostels and offices (Nkosi *et al.*, 2013:7).

Medical waste is produced by the medical clinic on campus and hazardous chemical waste is produced by the chemistry laboratory in the School of Education. Medical waste consists of cotton wool, bandages and empty vaccine containers and is removed by an outside contractor. Concerns regarding the handling of hazardous chemical waste, the storage of chemical substances and the containment of chemical spills are still relevant (NWU, 2012). Hazardous used chemical substances are stored in thick 10 L plastic containers in the chemistry laboratory. Operational documentation for chemical substances is in order and is available.

General waste is removed by the garden services provided by Magic Lawn, that collects bags with waste at various points on campus and move it to a central place where municipal services pick it up. Nkosi *et al*., (2013:11) mentioned that waste collection and transportation had to be critically thought of in South Africa to accommodate rapid urbanization, population growth, improvements in community health demands as well as better service.

Waste dumping of 1 ha of building materials in the north-eastern corner of the campus raised concern. The Legal Compliance Audit (2012) reveals that no evidence was found as it was licensed as a waste disposal site according to NEMWA (Act 59 of 2008). During the field trip the researcher and co-observer noticed that waste in the form of plastic bags and other rubble was even present in the blue gum woods. This corresponds with the findings of Nkosi *et al*. (2013:11) indicating that landfill waste create problems like wind dispersing debris; rodent, insect and bird infestation which can be disease carrying; pollution of ground and surface water and foul odours. Prof Linda du Plessis was notified of the situation in the woods and it was proposed to let the first year students of 2014 do an environmental clean-up activity which will familiarize them with the campus environment but also promote environmental awareness.

In summary it can be concluded that the amount of buildings on campus is directly proportional to the number of students and staff entering the focal

system, and directly proportional to the demand for water and energy as well as the production of waste. The amount of students on campus therefore drives the change in this system. Main issues resulting from this are increased waste generation, excessive use of land, degrading soil, air and water quality, as well as a threat to biodiversity. Waste management, according to health and safety regulations, as well as spatial planning and land use are manageable, therefore change in management principles and attitude make these predictable disturbances. The focal system, with access to the Vaal River and with various manmade dams on campus, has to give serious consideration to the impact of climate change on the immediate environment. Climate change not only affects biodiversity, but results as a serious economic and a health and safety challenge for both students and management.

In the next section the focus is on the historical timeline and its value for the focal system.

4.2.4 Historical timeline of the focal system

A timeline for the study area is presented with a focus on the main system events. The timeline covers decades from the 1980s to 2010 and beyond. The periods identified in the history of the focal system include: starting, disrupting, changing and expansion phases.

Increased demand by industries for more competent people especially engineers and accountants lead to the building of the NWU (Vaal) on the banks of the Vaal River. This activity is seen as the starting phase (De Klerk & Moller, 2005:481).

During the next, disrupting phase the decision to move the engineering faculty to the Potchefstroom Campus had a huge impact on the NWU (Vaal) with a drop in student numbers by over 400. The decision to incorporate English as a second lecturing language aided to stabilize the student numbers (De Klerk & Moller, 2005:478).

The third phase, the so-called changing phase saw the merger first with the Vista University of Sebokeng in 2002, and then the Potchefstroom and Mafikeng Campuses in 2004 in a multi-campus model. This put a higher

demand for available lecturing halls – therefore increased demand on land use, energy and water. The student profile changed rapidly to a campus with predominantly black students with white students in the minority Lecturing and administrative staff need to incorporate new personnel of other cultures and religions – a paradigm shift from the traditional campus culture (Annexure C: Student head count information 2000 – 2013; Du Plessis, 2013).

Expansion phase: Surviving the biggest change in campus culture, the campus is still flourishing and expanding still. New lecturing halls and a library have been built; the student profile changed once again for the NWU (Vaal) which is no more a university for the nearby communities but also accommodated students from other places in South Africa, Africa and the world. Although the immigrant students are few in numbers it is foreseen that these type of students can increase in the future. Du Plessis (2013) reported that the balance between pre and post degree students' needs to be addressed. The first part of the expansion phase was focused on aiding previously disadvantaged students to benefit by obtaining higher education. Now the shift needs to enhance higher education by supporting more students to obtain honours, masters' and doctorate degrees. This shift in vision on the academic side may change the student profile once more by incorporating students from other universities, nationally and globally, to study at the NWU (Vaal).

Table 4.3 reveals the historical timeline of the focal system in relation to the upper and smaller scale systems from 1980 to beyond 2010.

Table 4.3: Historical timeline of the focal system in relation to the upper and smaller scale systems

Larger scale system			
1980's	**1990's**	**2000's**	**2010's**
High demand on water via industries; limited recycling of water; demand for alternative water resources; influx of more people in area; longest drought in 20th century	Privatization of industries left many unemployed; flooding in 1996	Unemployment is still a reality; catchment degrade; demands from community for upliftment of catchment; community forums as voluntary management emerged; heavy rain and flooding in 2006	Unemployment is still a reality; pollution of the catchment visible in fish deaths due to sewage and industrial spills; air pollution in CO_2 emissions relevant; Poor management and old equipment blamed; flooding 2010 and 2011; drought in 2013; Vaal Environment Justice Alliance demand access to information from industries
Focal system			
1980's	**1990's**	**2000's**	**2010's**
1983 Vaal Campus at present location; Student numbers 1147; First residents on campus in hostels Starting phase	1994 drop in student numbers (1500) (Engineering faculty to Potch) Incorporate English as second lecturing medium; merging with Vista University Biodiversity increase Disrupting phase	2003 student number 2247 Merging of 3 campuses – student numbers 2009 (4506) Change in biodiversity – testing phase Changing phase;	Phase of rapid increase in student numbers; 2010(5213) to 2013 (6209) – increase of 1000 in 3 years; Increase in land use – Expansion phase;
Smaller scale systems			
1980's	**1990's**	**2000's**	**2010's**
Students predominantly white	Student profile change with the incorporation of English as a medium; more money available from government for previous disadvantaged students.	Student profile change still becoming a multicultural campus; Governance of campus change with the Institutional Office	Student activism for environmental issues became relevant; sustainable management of campus an increasing challenge with more activities to control. International students came to the NWU(Vaal)

From the historical timeline it is evident that two changes, each in the upper and smaller scale, trigger change in the focal system. The social dimension of the social-ecological system initiated change in both instances namely: in the upper scale the privatisation of industries and change in governance of the Vaal Barrage Catchment agree with change in the focal system. In the smaller scale the incorporation of English as a medium for lecturing as well as the change in student profile corresponded with change in the focal system. This cross scale interaction that a change in student profile, resulted in a change in student numbers placing a higher demand on the ecological component and threatens biodiversity on campus. The ecological trigger event which incorporates all scales is climate change. Critical interactions between the upper scale and both focal and small scale can be the quality and quantity of water.

In the next section the system dynamics are addressed.

4.3 SYSTEM DYNAMICS

Social-ecological systems can experience both gradual and rapid changes. To understand what drives these changes can reveal the vulnerabilities of a social-ecological system and create windows of opportunities to manage change in a social-ecological system (Resilience Alliance, 2010:22).

4.3.1 Change drivers

As indicated by the historical timeline socio-economic factors are responsible for the largest changes in the focal system. From the upper scale system, the unemployment of the local workers encouraged the community to use the local campus. Students staying with their parents, as day students attend the university.

The change in the management structure of the NWU due to national governance demand, with the Institutional Office as enforcer, created the current student profile (Du Plessis, 2013).

Ecologically climate change is regarded as the main concern which can create change in the social-ecological system. Higher demand on water and energy resources, lead to higher emission of greenhouse gases and production of

more waste and increased pollution. Degrading water, soil and air quality results from the latter (Van Wyk, 2013). Mbirimi (2010:246) supports Van Wyk and indicates that by 2020 globally 75 – 250 million people will be exposed to water stress due to climate change. Rain fed agriculture crops will reduce with 50 % meaning more people will have less access to food with increasing malnutrition. Mbirimi (2010:248) proposes that South Africa will experience serious water stress due to population growth and land use. Climate change will reveal the following dimensions according to Mbirimi: there will be an increase in the frequency and severity of climate events; better developed countries will have better capacity to withstand the ravages of climate change and South Africa will be vulnerable due to the fact that current responses to climate change is often only strategies to reduce poverty issues. Mbirimi indicates that in South Africa climate change has a big development dimension and the more broadly based the approach, the better the preparation for future scenarios will be.

4.3.2 Indicators of change

The following can be seen as indicators of change, therefore make change visible in the focal system:

(i) The available land and use of land as indicated by figures 4.2 and 4.3 – the campus plan before 2010 and after 2010 indicated a sufficient amount of area covered with buildings and facilities. More buildings are foreseen on the campus plan up to 2020 (Annexure D) which will result in a still higher demand for available land and resources.

(ii) The increase in student and staff number was already addressed and displayed in Chapter 3 (figure 3.1).

(iii) The generation of more waste and the use of resources like water and energy as displayed by the increase in human numbers (Nkosi *et al*., 2010).

(iv) Air pollution and air degradation is a result of building activities (dust) and the release of more greenhouse gases by more vehicles on campus.

(v) Climate change indicated by flood and drought information (*cf*. 4.2.4).

4.3.3 Alternate states and key factors

The main transitions in the focal system occurred during the 1990s and again in 2000s. Both transitions were linked to student numbers. Figure 4.2 reveals the alternate states and key factors responsible for transition in the focal system.

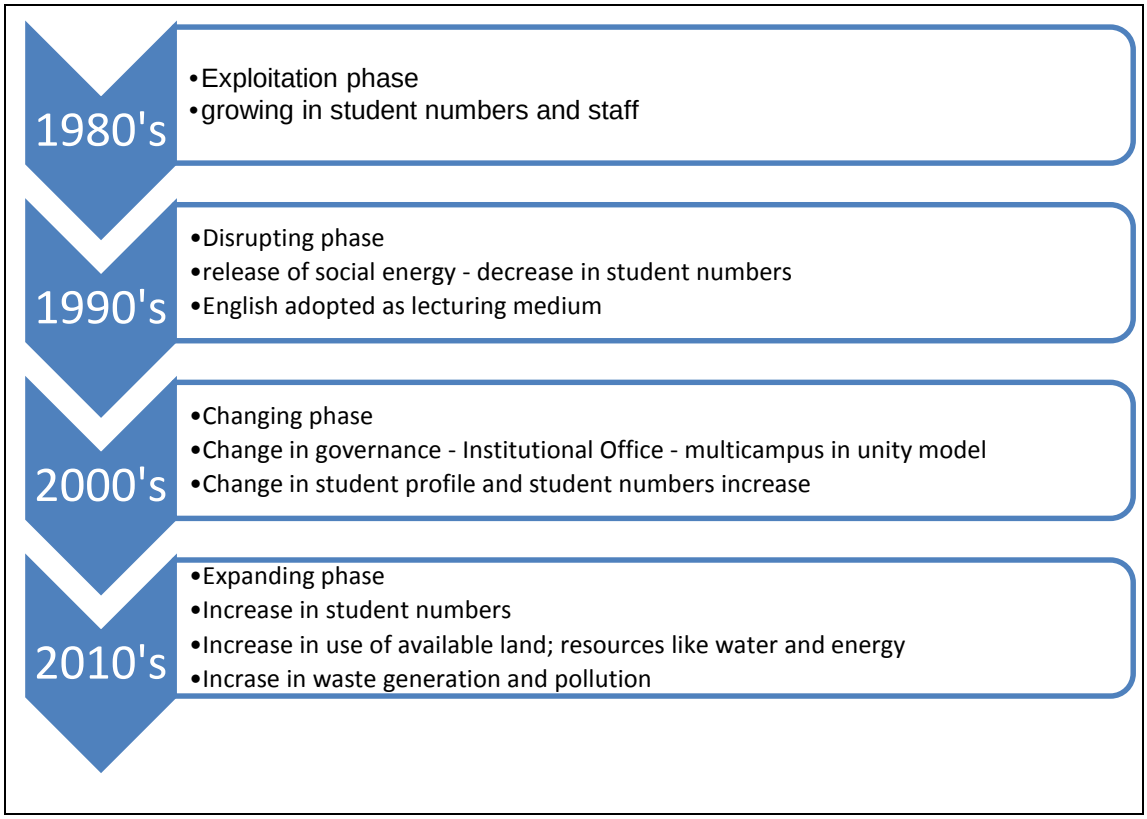


Figure 4.2: Transition with alternate states and key factors of the NWU (Vaal)

From the transition of the focal system it can be deducted that the system will never return to previous states due to the increase in variables like the amount of stake holders, number of participations and impacts on the environment. Desirable traits from the transition is a growing university providing more opportunities for people to get educated in better lecturing and research facilities. Undesirable traits include the use of more natural resources, less available land for biodiversity and an increase in various waste and pollution forms.

The next paragraph indicates the relation between alternated states, thresholds and transitions.

4.3.4 Thresholds and transitions

The number of students drives change in the focal system. Transition into altered states is planned and controlled by management of the NWU; therefore it is anticipated and accounted for. Movement into alternated states is not always smooth and gradual, but can be seen as a periodic occurrence with each new academic year. Slow changing variables which appear to be system drivers are climate change and the change in biodiversity.

The following thresholds are proposed for the focal system NWU (Vaal) namely:

(i) Climate change where an increase in temperature may result as unpredictable rainfall, visible as flooding or drought.

(ii) Change in biodiversity may be the result of climate change or due to excessive land use. This may endanger the wide open “feeling” and tranquillity on campus and result in negative responses by humans and stress on animals.

(iii) The use of available land. More buildings are proposed on the campus plan of 2010 to 2020. Concern is raised about what will happen to the wildlife with less available habitat.

(iv) The management system in the form of the Institutional Office situated in Potchefstroom. Concern is raised that the Institutional Office can be unaware of the real situation and demands of a specific campus, and therefore not responds with the needed resources or action.

(v) The general knowledge of students regarding the social-ecological system and unawareness how their actions influence the social-ecological system when littering, excessive use of water and energy, and lack of conservation initiatives.

Figure 4.3 reveals the relation between thresholds and their interaction with all scales.

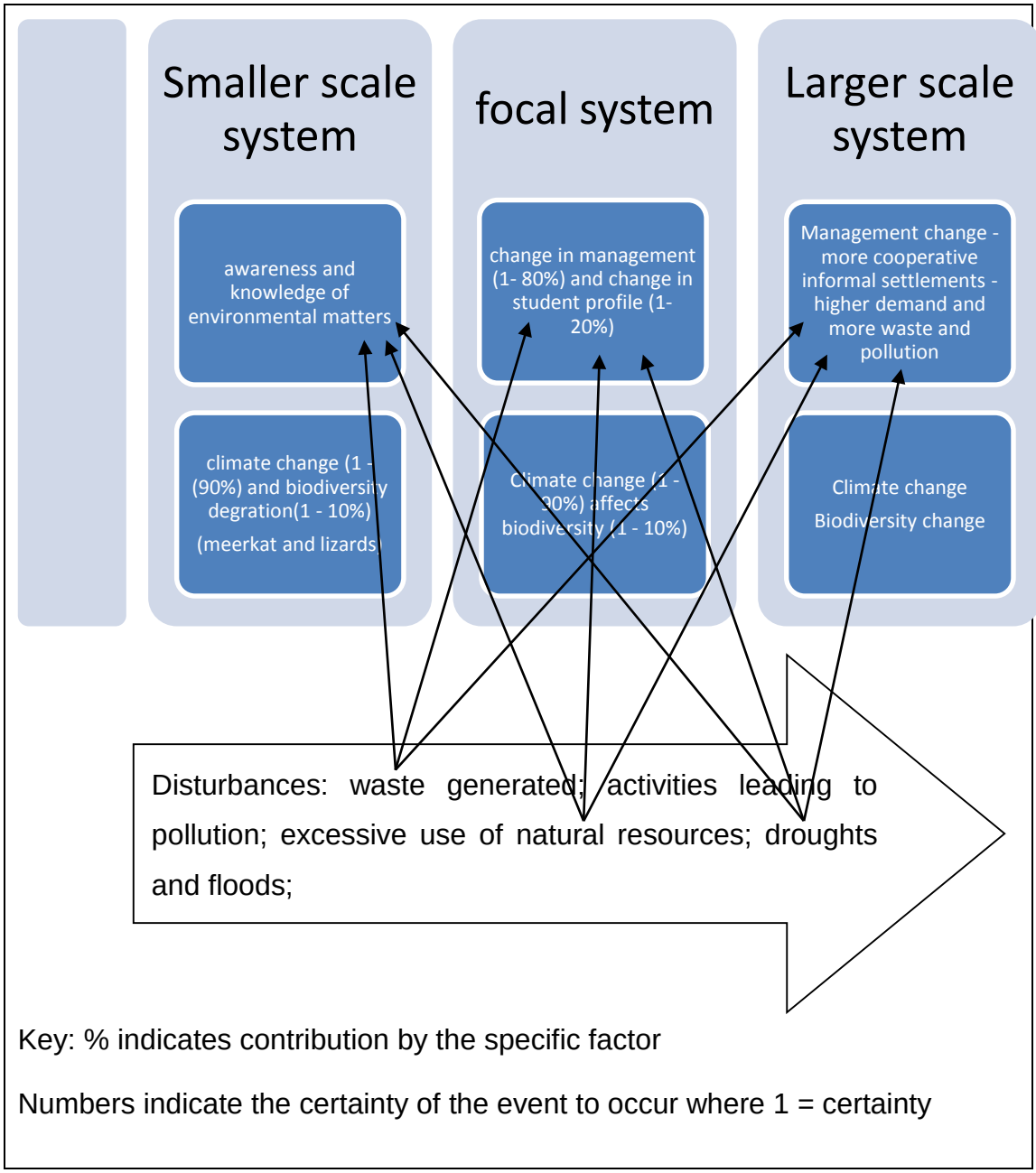


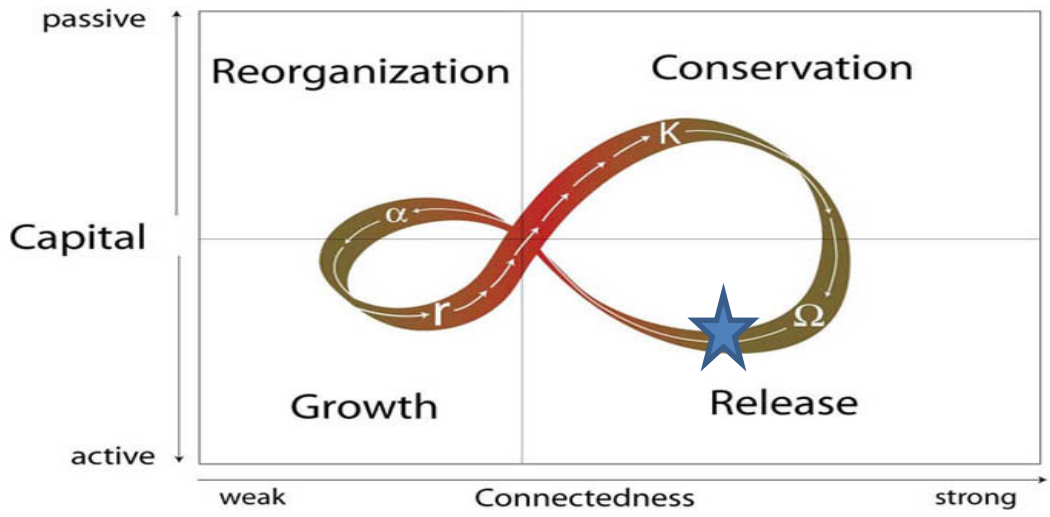
Figure 4.3: Thresholds and interactions diagram

To summarize it can be concluded that all thresholds are linked. If the available land decreases, biodiversity is influenced. Climate change affects all role players directly. An increase in day temperature leads to an increase in water evaporating, water levels will drop, the demand for water will increase, and less water will be available for humans and biodiversity. The Institutional Office will intervene with management demands via the campus management to mediate the water problem.

Having identified the disturbances and thresholds, the next section indicates the focal system in relation to the upper and smaller scale as a phase of the adaptive cycle. Each scale is represented in a separate adaptive cycle due to different variables interplaying in each scale.

4.3.5 Phase of the adaptive cycle

Both the upper and focal scale are in the release phase where high demand is placed on available resources, increased use of resources, depletion of land area and increased pollution and waste creation. The smaller scale system is in a growing phase. A possible cross scale interaction between the focal and smaller scale can lead to better preservation and use of natural resources. The correct use of natural resources will indicate to students the opportunism of the growth phase to enhance the release phase in the focal system. Figure 4.4 reveals the adaptive cycle for all scales.



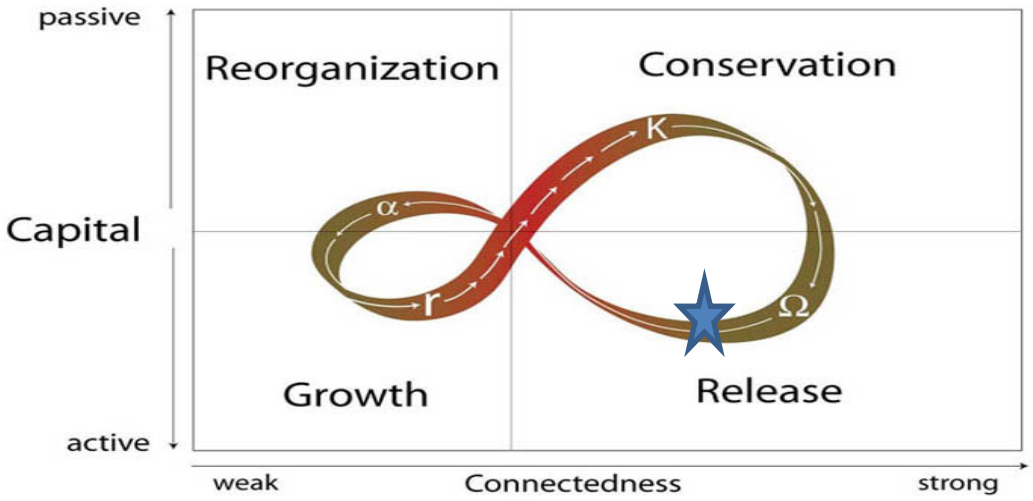
The **larger scale system** influences the focal system as follows: if Vaal River is polluted, in flood or drought the surrounding area (NWU Vaal) is directly influenced. Biodiversity (plant and animal life), as well as humans will experience direct change.

Sources of memory: previous drought and flooding; also previous pollution of water.

Sources of capital: abundance or scarcity of water

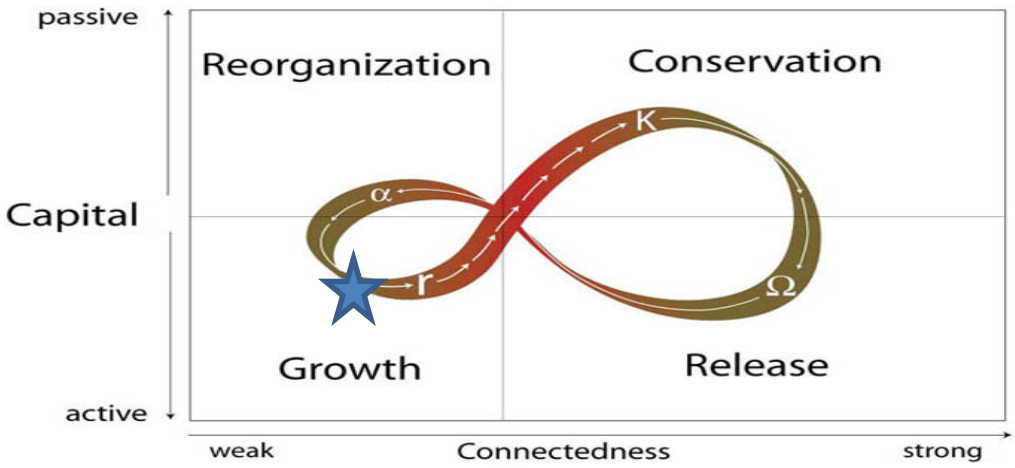
Social sources: Management of water in the Vaal River by Rand Water, municipality and forums

Ecological sources which manage water supply (quantity) and water quality.



Focal system

At this stage the larger scale system fosters the change in the focal system. Innovations and learning are coming from the smaller scale system which is in the growing phase. Better communication and education regarding ecological issues can enhance the opportunity to benefit from the current growth and change.



The **smaller scale system** is in a growth phase.

Ecological: the demand for available land and water resource are growing. Due to increased human population more waste is generated, and air and water pollution are increasing.

Social: Student numbers are increasing and according to the institutional policy the shift is to allocate more previous disadvantaged students. The student profile on campus is directed by institutional demand and is still expanding and changing.

Figure 4.4: Phases of the adaptive cycle of the focal system in relation to the upper and smaller scale systems

After identifying the phase of each scale in the adaptive phase, the states of the focal system is discussed.

4.3.6 States of the focal system

(i) **Historical state**

The historical state of the NWU (Vaal) sees a campus emerging from local demand, as a satellite campus of the Potchefstroom University, to a fully grown campus with high demand on natural resources and available land. The small number of staff and students and a gradual increase were easy to accommodate and control. Prediction of resource use and production of waste was certain.

(ii) **Current state**

The current state sees the exponential growth in student numbers. This high demand by student numbers triggered available land use, water and energy consumption and waste production. All of the latter has the implication of more waste that is generated. The dynamic character of the NWU (Vaal) with tranquil settings near the river and wildlife, seem to be exposed to elements that may swirl out of control. The balance between the flexibility and efficiency of the social-ecological system leads to the following trade-offs namely: increased student numbers and building versus the use of natural resources like soil and water; student demand versus available land and biodiversity; student demand for higher education versus campus character.

(iii) **Potential future states**

State: Effect of climate change

Climate change is a reality and will affect the social-ecological system. Change in average temperature, drought and flooding are all thresholds in all of the scale systems. The duration and severity of the natural phenomenon are unpredictable. Van Wyk (2013) reported that the current level of greenhouse gases have the ability to increase average temperature with 2 °C in the next 100 years. An increase of a global mean in temperature from 2,5 to 3 °C will lead to an extinction of 66 % of all animals. This indicates that the wildlife and biodiversity are threatened beyond repair.

State: Change in biodiversity

Decreasing available land may change biodiversity at the NWU (Vaal). Although our focus is on the wildlife, we tend to forget smaller animals like lizards and meercats have already lost their territory due to less shelter and food. Loss of biodiversity will change the campus character, making it a true city campus with buildings, roads and people and limited available tranquil areas.

State: Connectedness of a social-ecological system

Connectedness between ecosystem services and social structures on campus, as well as the rapid rate of change in student numbers and student profile do not allow available response time for the social-ecological system and may result as a spiral effect towards the completion or even failure of the system.

4.3.7 System dynamics summarized

As in the history of the campus, the focal system could change to potentially future states led by drivers of a more social nature. In the short term, changes in ecological aspects of the social-ecological system would be a consequence of a change in state and not a source of change.

It is therefore concluded that the attributes which pose the greatest threat to social resilience of the social-ecological system NWU (Vaal), are a lack of insight in the connectedness and relation between components of the social-ecological system; knowledge and attitudes in relation to the system's resilience and ignorance of the importance of resilience in the social-ecological system. Climate change is the biggest ecological threat to resilience.

In the next paragraphs future scenarios are presented to indicate specific outcomes for the focal system due to choices:

4.3.8 Proposal to move from current state to a state of environmental concern

To move from the current state of ignorance and supply by demand, the social-ecological system of the NWU (Vaal) needs to take cognisance of efforts by individuals or small groups to increase awareness of environmental matters. Money is made available by campus management to increase actions and awareness, but more stakeholders need to come on board to implement action (Tempelhoff, 2013). Prof Linda du Plessis confirmed that although the campus is proposed to accommodate 10 000 students, the management plan has foreseen about 8300 students by 2019 (Annexure E: Campus growth map). She indicated that the campus management was aware of the vulnerable ecosystem and would do everything possible to maintain the campus character of tranquillity and wildlife abundance (Du Plessis, 2013).

Regarding the biodiversity, Scholtz (2013) indicated that the black wildebeest (*Connochaetes gnou*) did not adapt well at the NWU (Vaal) and will be captured and sold soon. Wildebeest come in groups of ten, and act destructively on the environment causing erosion by making holes. The springbok (*Antidorcas marsupialis*) and blesbok (*Damaliscus pygargus*) that adapted well are smaller and require less extra nutrition making it the most suitable wildlife to keep on campus. This acknowledgement, to keep only wildlife which adapts well and does not stress the environment, can be seen as an action supporting sound environmental practices. Removing the wildebeest also agrees with legislative compliance regarding wildlife and supports the findings from the legal compliance audit of 2012 (NWU, 2012).

4.3.9 Proposal to move from current state to state of declining ecosystem services

The main driver to a future state of degrading ecosystem services come from the student numbers growing exponentially, thus putting a higher demand on available land and natural resources. Without sound management of environmental matter and proper spatial and land use planning for the NWU (Vaal) biodiversity and the character of the campus are in danger.

In the next section the governance of the focal system is revealed.

4.4 GOVERNANCE OF THE FOCAL SYSTEM

The governance system of a social-ecological system includes a variety of institutions and stakeholders, as well as multiple sectors and scales. Interactions between these entities determine how decisions are made, how power is shared and how responsibilities are displayed. Understanding governance is fundamental to understand interactions in the focal system (Resilience Alliance, 2010:36).

4.4.1 Key formal and informal institutions

Eight institutions, formal and informal, have been identified as relevant to decision making in the focal system and are discussed separately.

Institutional Office

The Institutional Office is responsible for strategic planning, policy development, allocation of resources to the campuses, designing the institutional process, branding and position as well as assures overall quality. The Institutional Office is therefore seen as the formal power of governance which interacts through formal meetings with the NWU (Vaal) campus management. The Institutional Office is directly involved by land use issues and the construction of buildings.

Universities autonomy is relative and not absolute, as it reacts on the national demands of the government. Figures set by the Minister for Higher Education in terms of increasing student numbers per year to give assess to previously aggrieved directed the Institutional Office approach (Stumph, 2008). Critique against the Institutional Office which supports the notion of being not flexible was found in The *Government Gazette* of 2 February 2009 and include notions that the implementation of this model is costly; it leads to unnecessary duplication of structures and services; the Institutional Office was bloated and getting bigger by the day; it creates communication uncertainties and indecision; an unfortunate side-effect result in campuses 'watching' each other in an attempt to outdo one another achieving extreme levels of self-sufficiency (*Government Gazette*, 35).

Campus management, NWU (Vaal)

Campus management has both formally and informally a strong power base. They meet with all stakeholders. Campus management is directly in charge of technical services and meets therefore with these staff through formal meetings. Campus management connects with other administrative and lecturing staff via email and formal functions like the official university opening and closing. They interact with contractors via project management and conduct meetings with students via the representative student board or informally via e mail, posters and announcements. Campus management meets the community formally in meetings and informally on social events like alumni get together and participation in community events like Cansa Walkathon or sporting events like golf days. Campus management may enhance flexible interactions with stakeholders like students and staff by encouraging waste reduction and reduced use of water and energy.

Technical services

Technical services and their staff are the implementers of all environmental practices on campus. They interact with campus management, contractors, all staff and students. The power of technical services is formally and informally intermediate in strength, and they are seen as flexible in their activities on campus.

Administrative and lecturing staff

Regarding governance administrative and lecturing staff have diverse to limited informal and formal power. The deans of faculties or managers of schools and units have formally more power than the average staff. This group interacts with students through formal lecturing and administrative tasks, technical services doing maintenance in buildings, campus management in official meetings and the community by actions to uplift poverty, increase skills and knowledge.

Students

Students have limited formal power by representation on the student and hostel boards. These representatives act formally on behalf of all students in meetings with campus management. Informally students have a broader

base of power. During July 2013 students reacted to environmentally related issues of concern on campus in quite a strong way by disrupting classes and voicing protests. Their main concerns were energy saving devises installed in hostels and safety at night off campus. Students were reported to use ovens as heaters during winter, and expect of campus management to install gates on various sides of the campus borders to accommodate them walking to and from the university (Du Plessis, 2013). These issues indicated their unawareness of environmental related issues and not knowledgeable regarding resource use.

Community

The community has formally no power, but informally they contribute by using facilities on campus. In this way they demand infrastructure and natural resource use and expect these services to be in impeccable form. This demand and their power to voice themselves if the situation is unsatisfactory through media like newspapers make the community a strong stakeholder.

Municipality

The municipality is the regional governance and representative of the national government for the campus. The formal power of the municipality was historically strong when they needed to give consent to the building of the campus. At that time they demanded evidence of extended planning (*cf*. 3.6.1). Their power is evident in their supply of water and energy, in the quality of water and energy supplied and waste removal. Failure to supply these services can place the campus in a bad position.

Outside contractors

Universities often rely on outside contractors for maintenance work and services. Building contractors work together with campus management to erect new buildings. This is usually a periodic service and once the building is signed off the responsibility, is transferred to the NWU. A nursery, Magic Lawn, aids to control the invasive plant species on campus and helps with garden planning and outlay (Annexure F). Cleaning services clean lecturing halls and offices, as well as rest rooms on campus. In the absence of a formal environmental code of practice given to these contractors, they may

contribute or erode resilience through their activities. Noise and dust generated through building activities increase pollution. Chemicals used by the nursery and cleaning services may degrade the environment.

4.4.2 Governance and decision-making relevant to the focal system

The larger focal scale is managed by Rand Water and the community based forums. This style of governance incorporated more stakeholder groups, which indicates an increase in diversity of role players. More diverse groups increase the resilience of the social system and add to direct the focus to more than one issue, therefore take into account different ecological changes. This increases the ability of the stakeholder group to respond to change and prepare better for disturbances (*cf.* 3.2.5).

The lower focal scale consists of separate groups which deal with issues according to their own view. Student activists promoting sound environmental management is limited in numbers and participation in real environmental issues lack commitment and need to be promoted (Vaalnews, 2013).

Figure 4.5: Photographs of an environmental clean-up action by student activists (Vaalnews, 2013)

The Institutional Office has the formal power to direct management practice on campus via the rector and management team. Stakeholder groups like students and the community have an informal powerbase and may increase their power by demands. Groups like these, use for example bold statements like press releases or student protest, to indicate if they are not satisfied with

management. Informal power is a very strong form of power expressed in bold and explicit action towards management to adhere to their demands. In environmental issues students have a strong point to express their demand and concern.

There are abundant tools to enhance communication between groups of stakeholders, but in practice the lack to express concern regarding environmental issues, hinders implementation of activities which may benefit the environment. Much can therefore be done to enhance collaboration between stakeholder groups.

Decision-making regarding environmental matters is limited to campus management and technical services to implement the initiatives of management. Getting more stakeholders on board may enhance implementation of environmental concern.

Campus management reports to the Institutional Office, although the NWU (Vaal) is seen as operationally not subjected to the Institutional Office and responsible for providing teaching and learning, conducting research and transfer expertise to the community via community services (Stumph, 2008:4). The focal system definitely lacks the incorporation of more role players. An initiative in 2012 to establish a commitment towards a green campus failed due to poor planning and communication between role players. Lecturers and administrative staff are encouraged by management to use water and energy sparingly, but due to a lack in monitoring and reporting of saving it result only in words and not actions. For 2014 more money is available to appoint a student in environmental management to promote and drive green initiatives in all spheres on campus. Only the future can tell if the initiative will pay off.

4.4.3 Rule enforcement and compliance

The freedom to pursue decisions is limited by the laws of the country and pertinent by the laws and formal government policies related to higher education. The following table 4.4 represents the laws relevant to environmental management on NWU (Vaal).

Table 4.4: Relevant environmental legislation and standards (NWU, 2012)

Resource	Relevant legislation
General	National Environmental Management Act (No. 107 of 1998)
Biodiversity	National Environmental Management: Biodiversity Act (No. 10 of 2004)
	Conservation of Agricultural Resources Act (No. 43 of 1983)
	GN R 151 in GG 29657 of 23 February 2007 (Lists of Critically Endangered, Endangered, Vulnerable and Protected Species)
Land Management	Conservation of Agricultural Resources Act (No. 43 of 1983)
	Fertilizers, Farm Feeds, Agricultural Remedies And Stock Remedies Act (No. 36 of 1947)
	Game Theft Act (No. 105 of 1991)
	Fencing Act (No. 31 of 1963)
Waste	National Environmental Management: Waste Act (No. 59 of 2008)
	GN 718 in GG 32368 of 2009-07-03 (Waste Management Activities)
	Human Tissue Act (No. 65 of 1983)
	Health Act (No.63 of 1977) Regulations relating to Food Premises and the Transportation
Hazardous waste	Occupational Health and Safety Act (No. 85 of 1993) Hazardous Substances Act (No.15 of 1973)

Legislation and laws are seen as command and control mechanisms to regulate environmental matters. Findings of the Legal Compliance Audit of 2012 on non-compliance of biodiversity regarding gemsbok and wildebeest were taken into account and relevant measures to comply with legislation were taken (Scholtz, 2013). Actions on invasive plant control and monitoring in the demarcated area where category 2 species are cultivated under control, were already started by technical services and indicate commitment to compliance from the side of the campus (Basson, 2013, Annexure F).

Initiatives to incorporate more role players in environmental management is started by campus management but processes are slow and do not indicate definite progress The lack of monitoring and reporting initiatives hinder transparent practice and belief in sound environmental management (Basson, 2013).

4.4.4 Conflicts and power relations

Due to various role players in the social-ecological of the NWU (Vaal) conflicts exist and interact on different levels regarding environmental matters. Conflicts include what top management regarded as important and what is best for the environment; initiatives to save water and energy and implementation of monitoring and reporting mechanisms; decisions regarding the way forward – the choice between campus character or student numbers; access to discussion/communication between stakeholder groups and environmental issues of concern; communication to contractor groups about environmental issues; and reporting on environmental issues to stakeholders and role players.

4.4.5 Social network among stakeholders

In figure 4.6 the social network among stakeholders is presented. The central group regarding power on campus is definitely campus management. All other groups are under “control” of this group. Students’ are a subgroup of the community, but are subjected to the lecturing and administrative staff. No group is isolated in the social network, but reports and responds to other groups. Technical services and contractors work together to deliver services.

Consultants have no real say in management but are necessary to complete certain services.

The central campus management acts in a management profile and therefore not necessarily represents the voice and interests of the stakeholders like students and staff. This can be a potential barrier in establishing social cohesion regarding environmental matters on campus.

The Institutional Office links the separate campuses. Each campus has its own unique student profile and culture. Demands from different campuses

cannot necessarily be addressed with the same urgency – this may hinder collaborative governance (Du Plessis, 2013).

In this scenario are multiple groups of actors with different roles and agendas to the social-ecological system. Social cohesiveness is difficult to reach due to a variety of perspectives and diverse approaches. Maintaining specialized knowledge and expertise is a goal to strive for. Isolated social groups whose voice is not heard can pose a barrier to social cohesion.

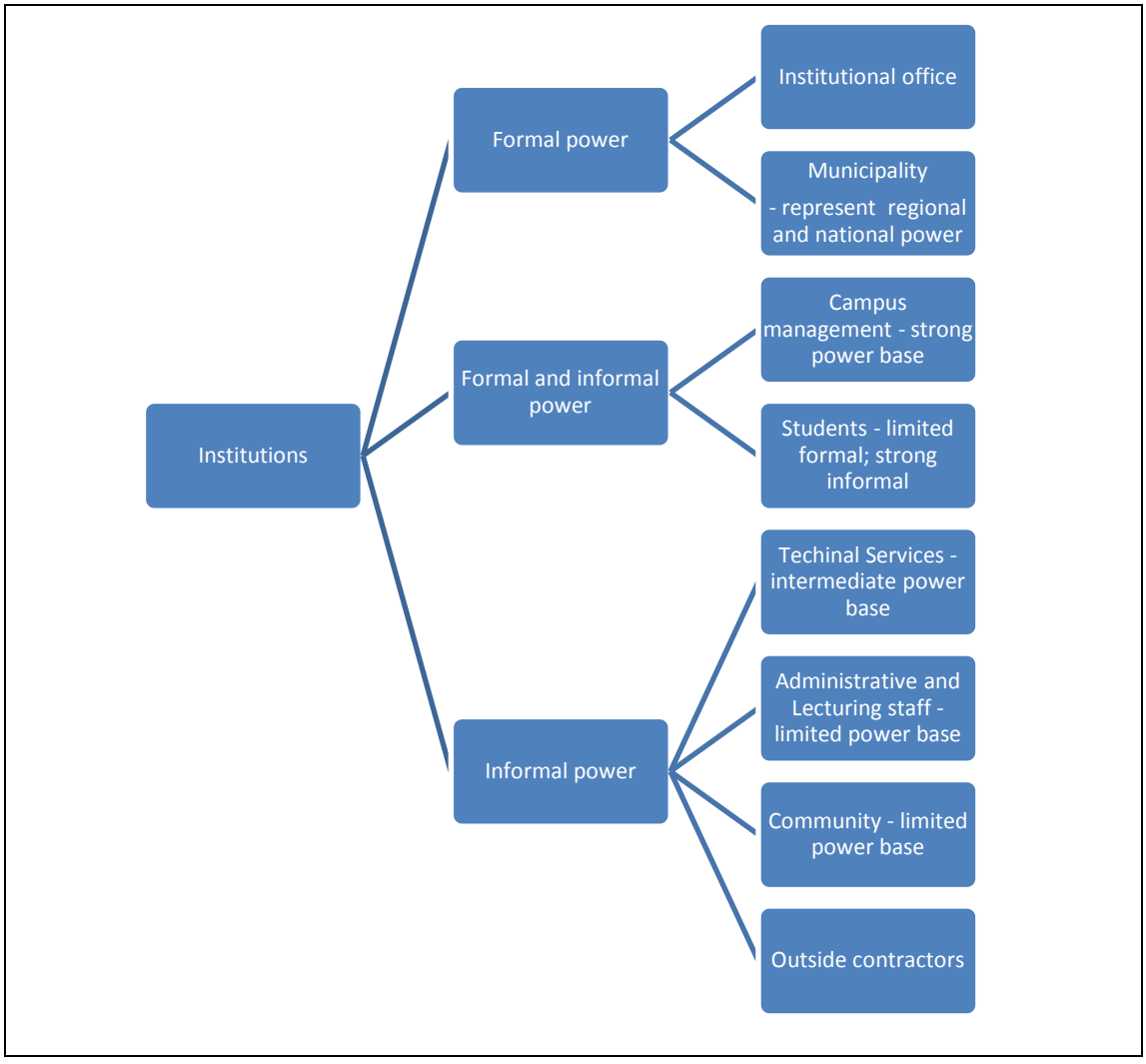


Figure 4.6: Social networks among stakeholders at the NWU (Vaal)

4.5 CONCEPTUAL MODEL OF THE FOCAL SYSTEM

A conceptual model of the social-ecological system of the NWU (Vaal) is constructed to indicate the relation due to external control in the upper scale. External controls, like poor air and water quality, cannot be controlled by the social-ecological system and influence the social-ecological system directly.

Poor air and water quality due to activities of various role players like informal settlements and industries will result in health and safety issues for the social-ecological system of NWU (Vaal). A change in external governance can hinder or enhance progress of the focal social-ecological system. Especially the supply of water to the various manmade dams, and the gardens and biodiversity that benefit from these dams on campus, is here of concern.

Governance of the focal social-ecological system is done by the Institutional Office via campus management. The main focus is demand for resources like water, energy, available land and buildings and maintenance of the mentioned and not necessarily environmental concerns. Various stakeholders of the social-ecological system benefit or lose if ecosystem services are poor or fail to comply with demand.

4.5.1 Scale above the focal system

The scale above the focal system consists of the Vaal Barrage Catchment, and especially the 3 km river front bordering the grounds of the NWU (Vaal). The Vaal Barrage is a water way of importance in the supply of quality and quantity water to the Witwatersrand and the lower Vaal for agriculture. Change in the governance of water, with more input by local municipalities and communities in the form of the Vaal Justice Alliance and forum groups influence the focal system (Vaal Environmental Community News, 2012). Ecological dimensions like drought or flooding in the catchment area, as well as increased pollution and water misuse by other consumers and industries will affect the focal system (Tempelhoff, *et al*., 2007).

4.5.2 Scale below the focal system

Smaller groups in the focal system, like student activism or lack of student action can promote or degrade the resilience of the focal system. Positive student activism like the supporting of Earth Hour (24/7) campaign for energy saving and environmental clean-up actions enhances resilience in the social-ecological system. Negligence regarding water and energy consumption; excessive waste production; the lack of recycling initiatives by smaller groups beneath the focal system inhibits resilience regarding environmental matters.

Taking into account all available information the conceptual model of the NWU (Vaal) was constructed and is displayed in figure 4.7.

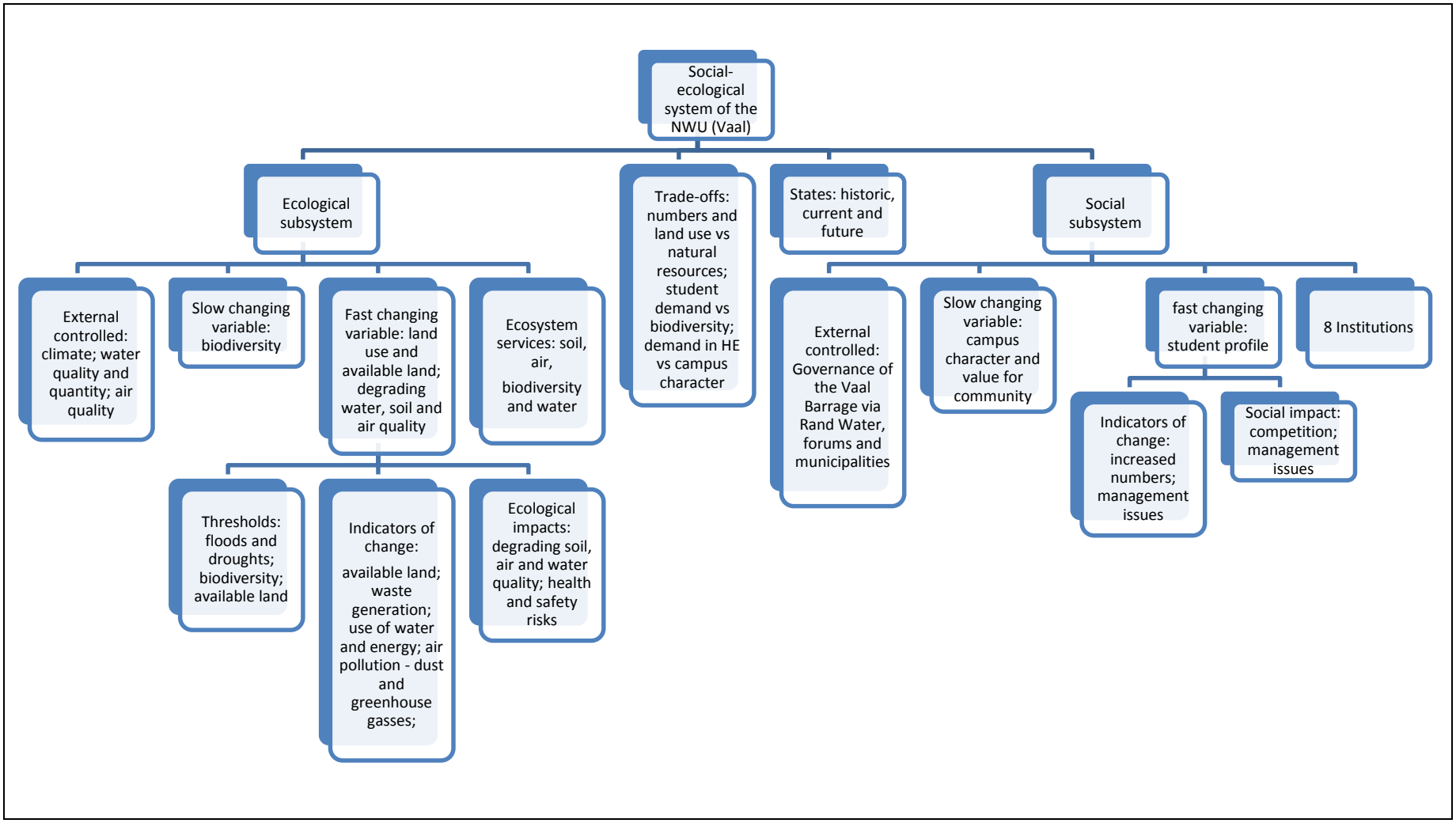


Figure 4.7: Conceptual model of the social-ecological system (SES) at the NWU (Vaal)

The conceptual model indicates that variables like air and water quality and quantity cannot be controlled by the governance structures of NWU (Vaal). Campus management has the power to reduce excessive water and energy use through various initiatives which may include command and control mechanisms, or incentives to role players who meet targets. The value of the NWU (Vaal) for the community is a slow changing variable and the aim must be to preserve the tranquil, aesthetic character of the campus. Fast changing variables in the social-ecological system include the amount of land which is used and activities which degrade water and air quality and generate waste. This may result in degrading of natural resources and health and safety issues. Due to national demand the infrastructure is increasing to accommodate a growing number of students. With it, the change in student profile over the last 5 years was exponential and the possibility of more change in the form of international diversity exists. Governance focuses mostly on demand and maintenance of facilities. The researcher wants to emphasize that the slow changing variables of biodiversity and campus character, are to her knowledge, the most valuable attributes to retain resilience and the focus of proposed actions must therefore be towards it.

In the following section resilience-based stewardship (Resilience Alliance, 2010) is proposed as actions and strategies which the social-ecological system of the NWU (Vaal) can embark on to enhance the focal system to a state of environmental concern.

4.6 RESILIENCE-BASED STEWARDSHIP

The focal system is currently not heading to a threshold due to sound planning and the ample use of available land. The campus was planned for 10 000 students, and the current student numbers are about 6000. But, to increase the biodiversity on campus by bringing in wildlife in the 1980s changed the whole perspective on environmental management. The researcher believes that in order to accommodate this decision of management, more awareness and consideration in the planning of future land use needs to be done at present. A change in managerial approach to this matter will be in the interest of both the ecological and social stakeholders.

The known: Environmental matters are managed by Technical Services which are not only responsible for the management of the ecological but for all maintenance services on campus. These people are not necessarily trained to incorporate environmental concerns in the way that they act. Services like cleaning of offices and lecturing halls are not necessarily managed by technical services, but are in the hands of contractors who may also not incorporate environmental concern in practice.

The unknown: To which level is campus management committed to take into consideration the ecological and environmental concerns?

To address this last question the following strategies and actions are proposed.

This research found that a stewardship strategy to improve social and ecological resilience at the NWU (Vaal) requires a change in governance and stakeholder approach. A stewardship strategy holds that we can and should manage the earth to our benefit, but we are ethically responsible to care for the earth by encouraging beneficial growth and development actions and discourage environmentally destructive actions (Miller & Spoolman, 2012:24). The change promoted by the stewardship strategy can occur at various levels as indicated by the following description of the goals which is necessary to implement this strategy.

4.6.1 Organizational change

To incorporate relevant environmental concerns in all land use planning and to communicate environmental related activities clearly and transparently to role players can enhance the maintenance of resilience of the social-ecological system.

Environmental actions should first be practiced on campus by encouraging and monitoring waste reduction and recycling before attempts can be made to make the community aware of such practices. The incorporation of an environmental management team with expertise in various environmental matters is proposed, with a permanent position for an overarching environmental manager at NWU (Institutional Office) and deputy environmental managers on campuses.

Challenges to bring about organizational change can be the lack of available economic resources; lack of knowledge and unwillingness to adapt to a new approach regarding environmental concerns and an already high workload of responsible parties.

4.6.2 Bridging science and policy

The set of an environmental management policy for campuses by the Institutional Office, with goals and objectives, is necessary to promote sound environmental management.

Institutional jargon and a lack of trust between role players who set the policy may hinder this process.

4.6.3 Changing public perceptions

The NWU (Vaal) may indicate public commitment to sound environmental management in the form of newspaper reports in the local newspaper. This action will raise environmental awareness and indicates to the community transparent practices and commitment to environmental management.

To change public perceptions will require different resources, human and economic. To find available and knowledgeable personnel to manage this may be a challenge.

4.6.4 Facilitating community participation and public consultation

NWU (Vaal) is situated in an industrial area where industries need to comply with legislation and environmental systems and plans of practice. By incorporating specialists from industry to invest their knowledge and aid with environmental data like water monitoring and air emissions reports are a matter of planning meetings and the setting of regular updates.

Different views from industries and campus management on environmental practices and a lack of leadership in both parties to establish trust may hinder implementation.

4.6.5 Gaining political support

The need to influence management to change their approach to environmental matters; ways to monitor their attitude towards change and finding staff members with dedication and concern for environmental matters is a huge challenge, but a must for sound environmental management.

Incorporating students in environmental actions can be done as follows: set a fixed position for an environmental leader on the student board. Hostel committees must also incorporate the position of an environmental officer who manages and advises sound environmental practices in hostels and on campus like waste reduction; waste recycling; responsible use of water and energy. These student leaders can make environmental actions per term explicitly visible like part taking in the 24/7 Earth hour initiative; arranging competitions between faculties, hostels, student committees to create awareness and save natural resources. The adding of a compulsory module on environmental awareness and responsibility for first year students is, according to the knowledge of the researcher, a necessity.

Lack of leadership to promote sustainable principles and opposing views in planning and the implementation of environmental practices may challenge this goal.

Figure 4.8 indicates a summary of the stewardship based approach to support a social-ecological system.

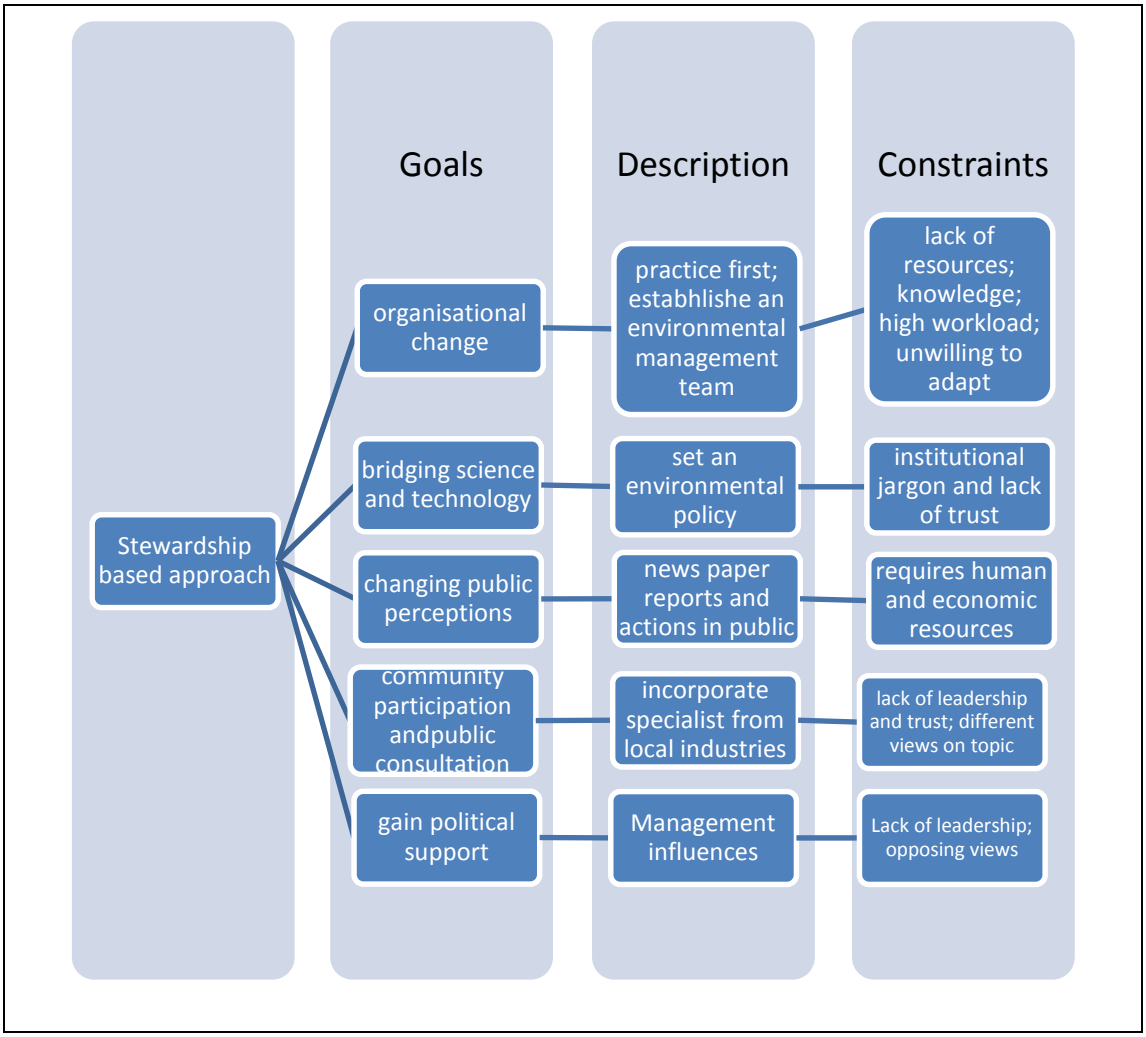


Figure 4.8: The stewardship based approach to support a social-ecological system

4.7 SUMMARY OF CHAPTER

In this chapter the results of the resilience assessment approach in conjunction with other forms of data were discussed. Ecologically have slow changing variables like climate change, waste generation and excessive land use by buildings the biggest effect on the social-ecological system. The main driving force behind change seemed to be the national demand to allow more students to enter higher education facilities. The rapid change in student profile and management structures poses a threat to the balance of the social-ecological system. Relevant thresholds identified which erode resilience of the social-ecological system include climate change, biodiversity change as a result of climate change and human activity, excessive use of land, management of campus and a lack of knowledge and awareness among

students. The chapter concluded with a proposal to follow a stewardship based approach to enhance environmental concerns.

In Chapter 5 the researcher will report on reaching the aim and objectives of this research study. Challenges will be addressed and possible actions and strategies will be revealed to aid resilience of the social-ecological system of the NWU (Vaal). A model will be constructed as a proposal for environmental management at the NWU based on the stewardship based approach. Proposals for future research will be made.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter provides information regarding the following:

- Findings from the literature review
- Findings from the empirical research in relation to the aims of the study
- Recommendations
- Limitations of the study
- Suggestions for further research

5.2 FINDINGS

5.2.1 Findings from the literature review

The literature review aimed to set the rationale for this research study. University campuses are seen as small towns regarding the consumption of energy and materials and the generation of waste. The academic freedom and research possibilities available at university campuses make it most suitable for research regarding social and ecological interactions (*cf*. 3.1).

Resilience is defined as the capacity of a system to persist within a domain or state in the face of change and is therefore a measure of the ability of a system to absorb change of different variables and adapt to change (*cf.* 3.2).

Two types of resilience exists namely ecosystem resilience as mentioned in the paragraph above and equilibrium resilience which refers to efficiency, constancy and predictability which reflect command and control approaches with a fail-safe design. The latter definition is not desirable because it considers systems to be static and intent a mechanistic approach towards social-ecological system (*cf*. 3.2.2). Using the definition of ecosystem

resilience which indicates adaptation to change enhanced the resilience assessment approach and is favoured in this research study.

A source of resilience in social-ecological system relevant to this research study is biodiversity. It is not the number of species which is critical, but rather the functional groups. This is true for the NWU (Vaal) campus where the participation of diverse groups, of different cultures with diverse skills, strengths and resources in decision making and structuring may add to resilience (*cf*. 3.2.3).

Another source of resilience is green spaces which have the ability to reduce domestic violence, quicken healing time and reduce stress by improving physical health and bring cognitive and psychological benefits to people. Green spaces at the NWU (Vaal) foster a sense of safety and belonging to students and staff, working and living on campus. It therefore aids to resist social, psychological, political and economic harsh conditions. At the NWU (Vaal) green spaces contribute to landscape heterogeneity with a variety of genetic, species and landscape diversity (*cf*. 3.2.3).

The loss of resilience is known as surprise and is a qualitative disagreement between the ecosystem and human expectations. At the NWU (Vaal) surprise occurred in the form of floods and droughts, which are unexpected events. These events revealed opportunities of learning and new knowledge. A rising flood line may aid with future planning of buildings and grounds. Drought revealed that a species, like the black wildebeest, is unsuitable to stay on campus due to the need for additional feeding and erosion of soil resulting from the animals' activity during harsh conditions (*cf*. 3.2.4).

Adaptation is the process of structural change in response to external circumstances. This re-activity of the social-ecological system revealed that the NWU (Vaal) (*cf.* 3.3.2) is currently in a release phase where natural resources are used. Opportunities from this phase include learning from previous cycles and innovations to incorporate new events in more sustainable ways.

The aim of the resilience assessment approach is to add long term benefits to human well-being by a process consisting of strategic questions and activities

to guide the researcher to construct a conceptual model of the focal social-ecological system (*cf*. 3.4.1). The conceptual model of the NWU (Vaal) proposed may aid decision makers like the Institutional Office and campus management to see the interconnectedness between the social and ecological components.

A social-ecological system is a complex adaptive system consisting of various dimensions like social, ecological and cultural components, having the ability to indicate degrees of change and uncertainty (*cf*. 3.5). The social-ecological system of the NWU (Vaal) consists of 8 institutions or role players. The campus management is seen as the formal governor and students, as the informal governor, with the most significant influence.

In the next section the findings from the empirical research is revealed.

5.2.2 Findings from the empirical research in relation to the aims of the study

5.2.2.1 Main aim

The main aim of this research study was to evaluate the social-ecological system to determine the resilience of the NWU (Vaal). The resilience assessment approach revealed that the focal system is currently in a release phase of the adaptive cycle (*cf*. 4.3.5). The release phase is often known as the end phase and a social-ecological system reaches this phase when external stresses force the system to enter a period of creative destruction when accumulated capital and structures are released.

The NWU (Vaal) is currently experiencing such a period of creative destruction with an exponential increase in student numbers which demand more facilities like lecturing halls, hostels and recreational grounds. Therefore more natural resources in the form of soil (land use), water and energy are used to construct buildings (*cf*. 4.2.3). Building activities also release dust which adds to air pollution. More students put a high demand on water and energy use, and generate more waste. All of these erode the resilience of the social-ecological system of NWU (Vaal).

The flexibility and efficiency of the social-ecological system at the NWU (Vaal) are threatened by the following trade-offs namely: increase in student numbers and buildings versus conservation of natural resources like soil and water; student demand for higher education versus tranquil campus character and biodiversity (*cf.* 4.4.4). The rapid increase in numbers and use of natural resources leave the system with little response time to adapt. This may threaten resilience of the system in future because limited memory is created, with the possibility of not allowing the system to keep to the natural adaptive cycle (*cf.* 4.3.1).

The following actions on campus aid to make the social-ecological system more resilient namely: available green spaces; richness in biodiversity; different stakeholders with difference in knowledge and approach to environmental management; students and staff of different nationalities and cultures; the incorporation of mechanisms to buffer the social-ecological system against the impact of disturbing events like knowledge and increased awareness regarding environmental actions (*cf*. 3.2.3).

Resilience is best expressed by phases of destruction and the ability of the NWU (Vaal) to reorganize and renew after disturbances which indicate enhancement or eroding of resilience (*cf.* 3.3.1). As the social-ecological system is still in the release phase, and will be for a few more years due to proposed spatial planning and prediction of more students, it is not possible to make a final statement about the NWU (Vaal) resilience.

Currently the NWU (Vaal) is still resilient and adapts well to rapid change. An increased awareness of environmental concerns by different institutions like campus management, technical services and students aid to enhance resilience. A final answer on the resilience of the NWU (Vaal) will never be absolute due to the ever changing state of the focal system (*cf.* 3.2.1). It can therefore be concluded that periodic re-assessment of the social-ecological system of the NWU (Vaal) will aid with planning and decision-making to enhance resilience and sustainability of the campus.

Findings in relation to objectives:

Objective 1: Identify possible disturbances to environmental resilience at the NWU (Vaal).

Ecological disturbances relevant to the social-ecological system of the NWU (Vaal) include the continuation built of new buildings, climate change and increased waste generation. The effects of climate change are already visible in more frequent and unpredictable conditions of droughts and floods. The continuation of buildings and waste generation are controllable disturbances for the governance of the social-ecological system (*cf.* 4.2.4).

The historical timeline revealed that two social initiated events set the focal system in alternated states namely: the decision to move the engineering faculty to the Potchefstroom Campus in the 1990s and the merger with the Potchefstroom and Mafikeng campuses, as well as the Vista University of Sebokeng in the early 2000s. The first resulted in a decrease in student numbers and the latter in an increase in student numbers (*cf*. 4.2.4).

In the upper scale economic events like the privatization of industries and unemployment of many residents in the local community support the NWU (Vaal) as a higher education option for more students (*cf.* 4.2.4).

Indicators of change are the available land and use of land as seen on different campus plans; the increase in student and staff numbers from official documents of the NWU; the generation of waste; air pollution and air degradation due to building activities as well as climate change as indicated by drought and flood information (*cf*. 4.3.2).

The driver of all change in the social-ecological system was identified as the national demand for accommodating more previously disadvantage students in the domain of higher education. Thresholds proposing to have the ability to flip the social-ecological system into alternated states include: ecological climate change; a change in biodiversity; excessive use of available land; in social terms the management system of the NWU and a general lack of knowledge and awareness on how human actions influence the resilience of the social-ecological system of NWU (Vaal) (*cf*. 4.3.4).

In summary it can be concluded that both ecological and social disturbances were identified which impact the focal system. Often ecological disturbances are controllable like waste management, but social disturbances call for a more collaborative approach and communication between affected parties. Disturbances, as a topic therefore create opportunities within a social-ecological system to engage with and learn from others

Objective 2: Construct a conceptual model of the social-ecological system of NWU (Vaal).

The construction of a conceptual model of the social-ecological system of NWU (Vaal) was a challenging task and called for the incorporation of components like: defining the focal system; identifying disturbances; constructing a time line over four decades; incorporating system dynamics like change drivers, indicators of change, alternate states, phases in the adaptive cycle and governance (*cf*. 4.2 - 4.5).

Challenges in the construction of the conceptual model

This is the first research study to follow the resilience assessment approach to determine the resilience status of a university campus, therefore relevant literature to direct the study was limited.

Resilience assessment is seen as a new form of environmental impact assessment (EIA) and available sources were limited although the Resilience Alliance website aided to direct this research study.

Resilience assessment supports sustainable development and it is a difficult concept to assess if it is not explicitly incorporated in documents of the system being studied.

Each resilience assessment is unique, site specific and relate to no other. Therefore no two conceptual models will have the same elements. Decisions on relevant concepts to include in the conceptual model were challenging.

The resilience assessment approach has a reflective nature and concepts are often revisited. Decisions of the most relevant concepts to include in the conceptual model may differ from researcher to researcher.

Value of the conceptual model

The conceptual model is a unique construction in a specific time frame of the research period. Some of the components, which form part of the model for 2013, can possibly not be relevant later and therefore the model needs to be interpreted to aid with decision making in the current state.

The conceptual model is like a big picture of the current status of the social-ecological system of the NWU (Vaal) and aids to provide valuable information to campus management regarding external - and internal controlled issues in both the ecological and social component. Knowing what you can manage and what not, may save time and money.

Trade-offs suggest debatable issues and thresholds, possible boundaries, which if once crossed, may result in a new state for the social-ecological system. Fast changing variables, like water and energy use or changing student profiles, need to be managed and often incorporate legislation and a set of rules. Slow changing variables, like preserving biodiversity and tranquil campus character, are more difficult to manage because it requires the changing of attitudes and perceptions.

Awareness of the interconnectedness of the social-ecological system aid with balance in decision making and therefore the conceptual model is set as a balanced structure with the trade - offs or debatable issues as the anchoring point between the ecological and social components. Over emphasising one component may result in the tipping of the scale and disrupting the system (*cf.* 4.5).

In conclusion, the construction of a conceptual model was a challenging but rewarding task to enlighten knowledge and to gain insight in the social-ecological system of the NWU (Vaal).

Objective 3: To test the use of the resilience assessment approach for university campuses

The resilience assessment approach was applied to the social-ecological system of the NWU (Vaal) and available data and information of the NWU (Vaal) were interpreted to reveal the resilience status of the NWU (Vaal) (*cf*. 4) as indicated in the main aim.

The resilience assessment approach is mainly used to guide research of bigger ecosystems like the national parks, rangelands and river basins. Applying this approach to such a small social-ecological setting seemed to be inappropriate if compared to available research results. Despite the aforementioned, the resilience assessment approach is applicable to such a small social-ecological system and provided a structured framework which guided this research. Reflective questions and directions aid the researcher to revisit assumptions and keep focus on the main aim (*cf*. 3.4.1). The approach focused attention to attributes and role players valuable to the focal system, which could be ignored otherwise. Using the resilience assessment approach resulted in a long term benefit for both the environment and human beings who are part of the social-ecological system (*cf*. 4.2.3).

The resilience assessment approach aids to incorporate the resilience-base stewardship approach to direct environmental management of the NWU (Vaal). The stewardship strategy proposes sound environmental management with ethical responsibility and promotes the following implementation steps: clear and transparent communication among all institutions or role players and proposes integrated waste management with the focus on the reduction and recycling of waste; the development of an environmental policy for the NWU (Vaal) with an environmental management team responsible for environmental management issues; public commitment to sound environmental practices via newspapers and other media; the incorporation of specialists from nearby industries who can aid with the monitoring of resources and participate in research and the incorporation of students, as the most powerful informal governors, to participate in leadership roles; competitions on resource saving initiatives and to gain a basic knowledge and raise awareness on environmental matters (*cf.* 4.6).

Challenges to incorporate the stewardship strategy include a lack of economic resources and willing people with knowledge on environmental matters; institutional jargon and resistance to change; different views from stakeholders on the same issues and a lack of leadership to implement the proposed strategy.

Based on the stewardship strategy the researcher proposes the following model in figure 5.1 which may aid to implement environmental management at the North-West University.

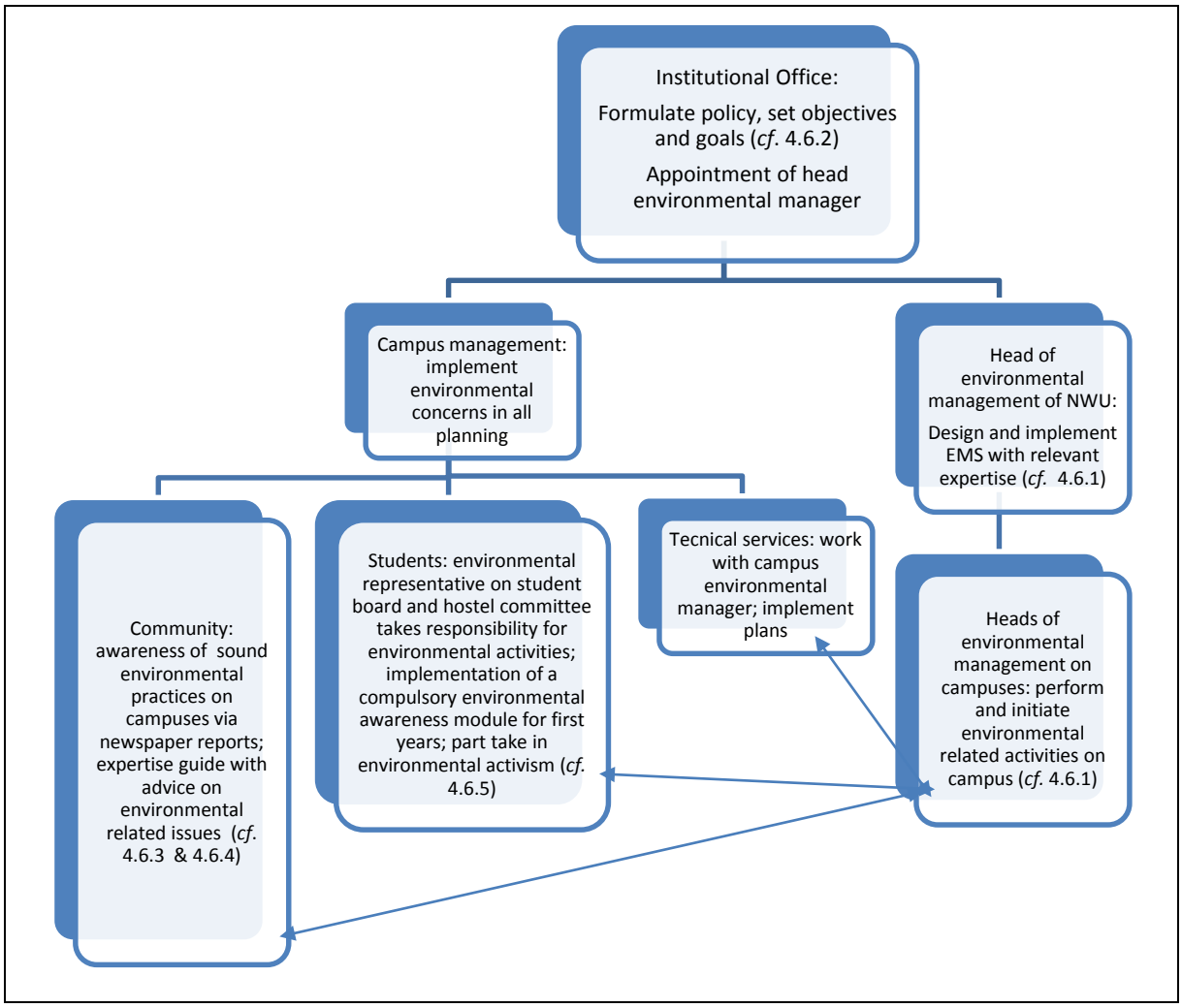


Figure 5.1: Proposed environmental management model for the NWU

It can be concluded that it is possible to use the resilience assessment approach on a small social-ecological system like the NWU (Vaal) and contributes to research on resilience and aids with environmental management.

5.3 LIMITATIONS OF THE STUDY

A number of limitations were identified in the research namely:

- This research study focused on the social and ecological dimensions of the social-ecological system under study but the economic dimension plays a big role especially in the maintenance and conservation of natural

resources. Implementation of progressive actions to enhance environmental matters also needs economic resources. The incorporation of the economic dimension will enhances sustainable development of the focal system in the research study.

- Due to time constraints the research period was only nine months. A longer more expanded time frame in the research field could contribute to more powerful findings.

5.4 RECOMMENDATIONS

In light of the findings, the following is recommended when using the resilience assessment approach to evaluate social-ecological systems:

- Each social-ecological system is unique and therefore researching a specific focal system demands various forms of data collection. Data appears in forms like dated historic information, quantitative sets of readings, qualitative descriptions and word of mouth assumptions. To confirm findings, different sets of data or different forms of data, is needed. The researcher therefore aims to confirm quantitative findings with qualitative confirmation and vice versa. Thus increasing construct validity (*cf*. 2.3.5).
- Observations are a crucial part of the assessment process. Findings from observations were confirmed by Mr Johan Strauss (Lecturer: Geography, School of Education). Mr Strauss acted as a co-observer and often data which was overlooked by the researcher was indicated by him. The use of a co-observer thus adds to the reliability of findings (*cf*. 2.3.5).
- Research of a social-ecological system demands good relations with various stakeholders and power forms. Keeping to ethical conduct and respect for the view of a specific stakeholder are a necessity to complete the research study (*cf.* 2.3.7).
- The choice of the focal social-ecological system needs to be done from a perspective of social concern and interest of the researcher. In this research study the concern of the researcher was: what is done at the

NWU (Vaal) regarding environmental management and how could environmental management at this campus be enhanced?

5.5 SUGGESTIONS FOR FURTHER RESEARCH

This research study made the researcher aware of the advantages of using a solid methodological framework like the resilience assessment approach to direct research. The following suggestions are made for further research:

- The resilience assessment approach can be performed by more than one researcher on the same focal system. After completion of the research, findings can be shared and compared. This method will enhance understanding and supplies rich data regarding the specific focal social-ecological system.
- The resilience assessment approach can be conducted by different researchers on similar research sites for example all the university campuses of the NWU or in South Africa. Findings can be shared and compared by looking for similarities and differences in variables.
- The same researcher can apply the resilience assessment approach to different campuses in different upper scale systems. For example comparing a coastal campus with an inland campus. The effect of the difference in the upper scale can be emphasized by this research study.
- Resilience assessment may enhance sustainable development and sustainability by combining resilience assessment with environmental impact assessment (EIA) in general.

5.6 CONCLUSION

The use of the resilience assessment approach to evaluate the social-ecological system of the NWU (Vaal) revealed that the NWU (Vaal) is currently resilient but the situation may change in the near future. The demand from national government to accommodate more previously disadvantaged students at the NWU (Vaal) campus can be seen as the main driver to put the campus in an alternative state.

The NWU (Vaal) is known as a nature reserve and praised as a campus with a tranquil character which promotes human well-being. The management of NWU (Vaal) made a choice way back in the 1980s to share the campus with other species. Resilience of the NWU (Vaal) entails more than preserving biodiversity, but also emphasises the ability of the social-ecological system to progresses and adapts despite pressuring demands on its natural and social resources.

Social change needs to be initiated from a management point of view where the Institutional Office takes the lead by providing a policy, goals and objectives to direct environmental management on campuses. The only way to direct the NWU (Vaal) to an environmental concerned scenario is to increase the responsibility base of stakeholders like involving students and staff with environmental matters. The proposed resilience-based stewardship approach to initiate transformation in the social-ecological system of NWU (Vaal) is worthy of an implementation.

The use of the resilience assessment approach as an environmental assessment approach contributed to enhance more than the biophysical component. The incorporation of the social component, which includes role players and stake holders, like students, lecturers, administrative and technical personnel as well as the governance structure of the campus, complemented the aims of sustainable development at universities.

The call for sustainable development is no longer the problem of industries and big corporations. Students and staff at universities are seen as the leaders in society and need to take this name tag seriously. The resilience assessment approach is based on the notion of revisiting concepts often. This repeated reflections lead to deep thought about social and ecological connections. In a social - ecological system components are interconnected and relationships exist between components. This generation of abstract thought about social-ecological connectedness improves the understanding of the relationship between nature and humans, living and non-living components and aids with successful intervention in systems where these relationships are under pressure.

The need to learn from previous actions is a necessity and therefore all role players need to commit to practice which will enhance the wellbeing of the environment and its inhabitants. Knowledge of a social-ecological system enhances learning. This research study indicated that current environmental practices on the NWU (Vaal) campus take into account the natural ability of the social-ecological system to adapt to change but also raised alert that the resilience of the social-ecological system of the NWU (Vaal) is fragile.

This research study can therefore be seen as transformational learning regarding the social-ecological system of the NWU (Vaal). Transformational learning is a key component to enhance the resilience of the social-ecological system of the NWU (Vaal). The time to think about and to incorporate sustainable actions to upkeep the resilience of the social-ecological system of the NWU (Vaal) has come.

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ANNEXURES

ANNEXURE A

Consent from Prof Mariba, campus rector of NWU (Vaal) for study

PO Box 1174, Vanderbijlpark
South Africa, 1900

Tel: 016 910-3111
Fax: 016 910-3116
Web: http://www.nwu.ac.za

Humanities: School of Education
Tel: (016) 9103097
Fax: (016)
Email: 12765074@nwu.ac.za

21 February 2013

Dear Prof. Mariba

Environmental Management Plan

I am a lecturer in the School of Education and studying for my M.Env.Man degree through the NWU, Potchefstroom Campus.

Part of my studies, is a mini dissertation on an environmental problem/challenge. After consultation with Mr. Frans Basson and relevant role players, I feel privileged to focus my study on our own campus and the successes and challenges we face environmentally wise on a daily basis.

I hereby ask your permission/consent to do my study on the campus of NWU, Vanderbijlpark. I can ensure you that I will, to the best of my ability, be loyal and present the situation of our campus in the best possible light.

Yours sincerely

Irene Muller

Original details: Irene Muller(12765074) C:\Users\12765074\Documents\brief - prof mariba.docm
21 February 2013

21/2/2013

Approval to do study on our campus granted.

ANNEXURE B

Confidentiality clause from Institutional Office of access to information

NORTH-WEST UNIVERSITY ®
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
INSTITUTIONAL OFFICE

Records Management and Administration

Confidentiality Clause for the granting of access to information in terms of the Promotion of Access to Information Act, 2 of 2000

I, full names Irene Muller for purposes of the undertaking of a:

Name of study: M Env Man - dissertation

Study leader: Prof. J. Tempelhoff, JA Wessels

Date study was approved: 19 August 2013

Date approved by Ethics Committee (if applicable):

Campus: Potchefstroom Campus

Faculty: Natural Science

E-mail address: 12765074@nwu.ac.za

undertake and agree to:

(a) only use, copy or otherwise replicate the sample of **information requested description**,

student numbers, staff numbers and residents in hostels on the NWU(Vaal Campus)

as extracted from the student administrative system of the NWU (herinafter referred to as "the Confidential Information") for the purposes as mentioned above (herinafter referred to as "**name of study**") and not to use the same for any other purpose whatsoever;

(b) ensure that only those officers and employees who are directly concerned with the carrying out of this tracer study have access to the Confidential Information on a strictly applied "need to know" basis and are informed of the confidential nature of it;

(c) keep the Confidential Information secret and confidential and shall not directly or indirectly disclose, publish, transfer, disseminate, copy or permit to be disclosed the same to any third party for any reason other than the study as described above without the prior written consent of the NWU's Institutional Registrar involved;

(d) destroy the Confidential Information if the **name of study**, for whatever reason, is not completed and shall inform the Institutional Registrar accordingly in writing.

(e) not publish any information which may by any means, make any person individually and personally identifiable.

ANNEXURE C

Student head count information 2000 – 2013

Student Headcount Enrolment - Campus

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT
INSTITUTIONAL OFFICE

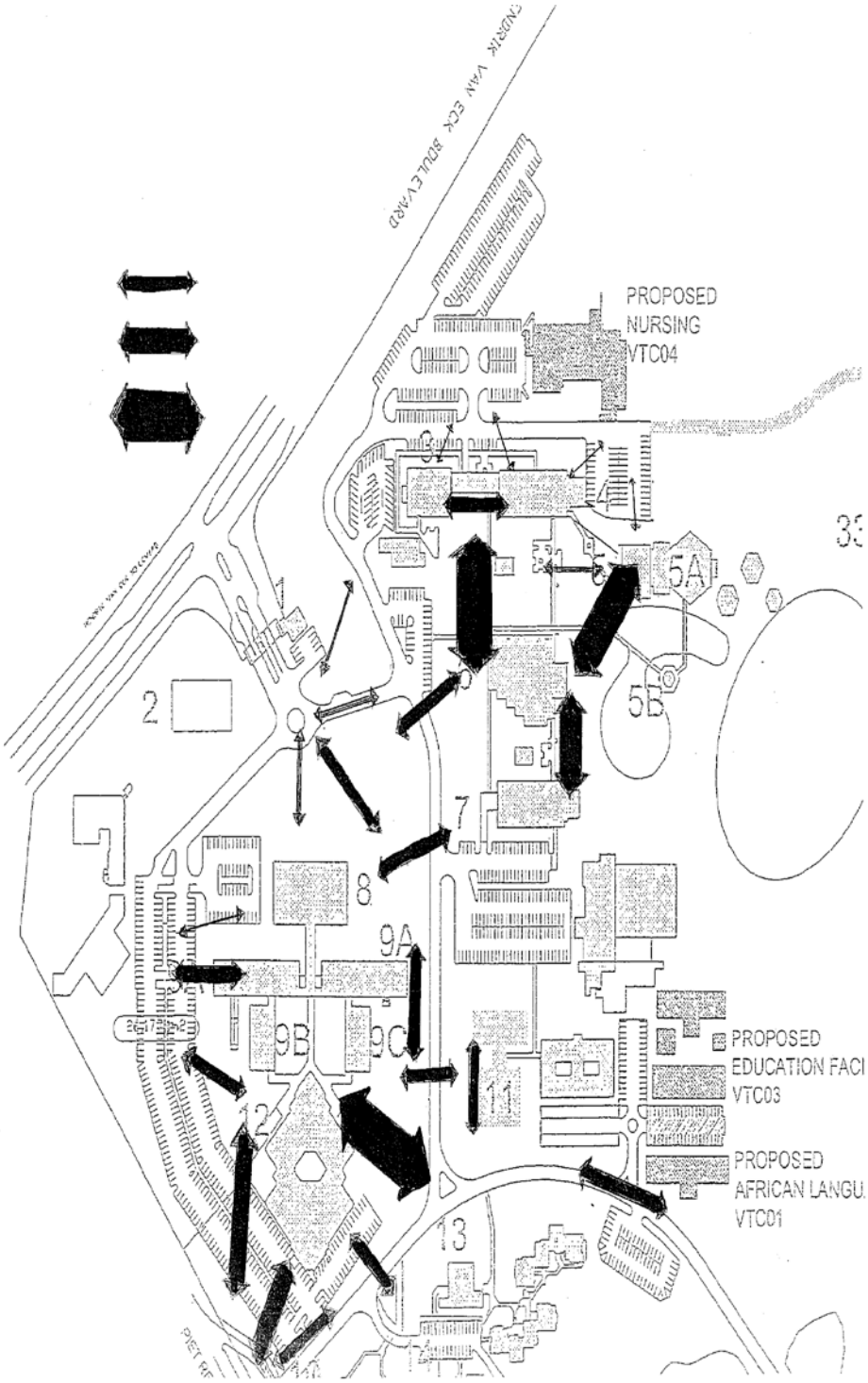
Management Information Report
B-INLIG@nwu.ac.za
+27 (0)18 299 4864

Run date 2013/11/15 14:35

Campus Rector	*Race*	*Gender*	2000 Final 2000-12	2001 Final 2001-12	2002 Final 2002-12	2003 Final 2003-12	2004 Final 2004-12	2005 Final 2005-12	2006 Final 2006-12	2007 Final 2007-12	2008 Final 2008-12	2009 Final 2009-12	2010 Final 2010-12	2011 Final 2011-12	2012 Final 2012-12	2013 Not Final 2013-10
9996 VTC Campus Rector	*Unknown	Female	4	5	8	11	144	70	37							
		Male	2	1	2	1	99	55	21	1	1	1	1			
			6	6	10	12	243	125	58	1	1	1	1			
	African	Female	207	196	296	634	941	993	1,107	1,147	1,513	1,982	2,316	2,550	2,895	3,086
		Male	209	222	263	480	714	803	813	786	918	1,086	1,261	1,402	1,650	1,840
			416	418	559	1,114	1,655	1,796	1,920	1,933	2,431	3,068	3,577	3,952	4,545	4,926
	Coloured	Female	14	17	21	29	16	21	29	38	36	57	79	75	83	78
		Male	6	4	15	18	20	21	22	17	19	17	29	29	31	31
			20	21	36	47	36	42	51	55	55	74	108	104	114	109
	Indian/Asian	Female	10	12	19	26	35	39	48	43	53	57	59	51	44	61
		Male	12	10	17	15	14	23	24	29	32	41	49	45	46	54
			22	22	36	41	49	62	72	72	85	98	108	96	90	115
	White	Female	406	425	494	524	612	691	746	766	756	823	940	912	928	923
		Male	415	432	442	385	443	491	517	499	416	442	479	472	480	486
			821	857	936	909	1,055	1,182	1,263	1,265	1,172	1,265	1,419	1,384	1,408	1,409
	Total		1,285	1,324	1,577	2,123	3,038	3,207	3,364	3,326	3,744	4,506	5,213	5,536	6,157	6,559

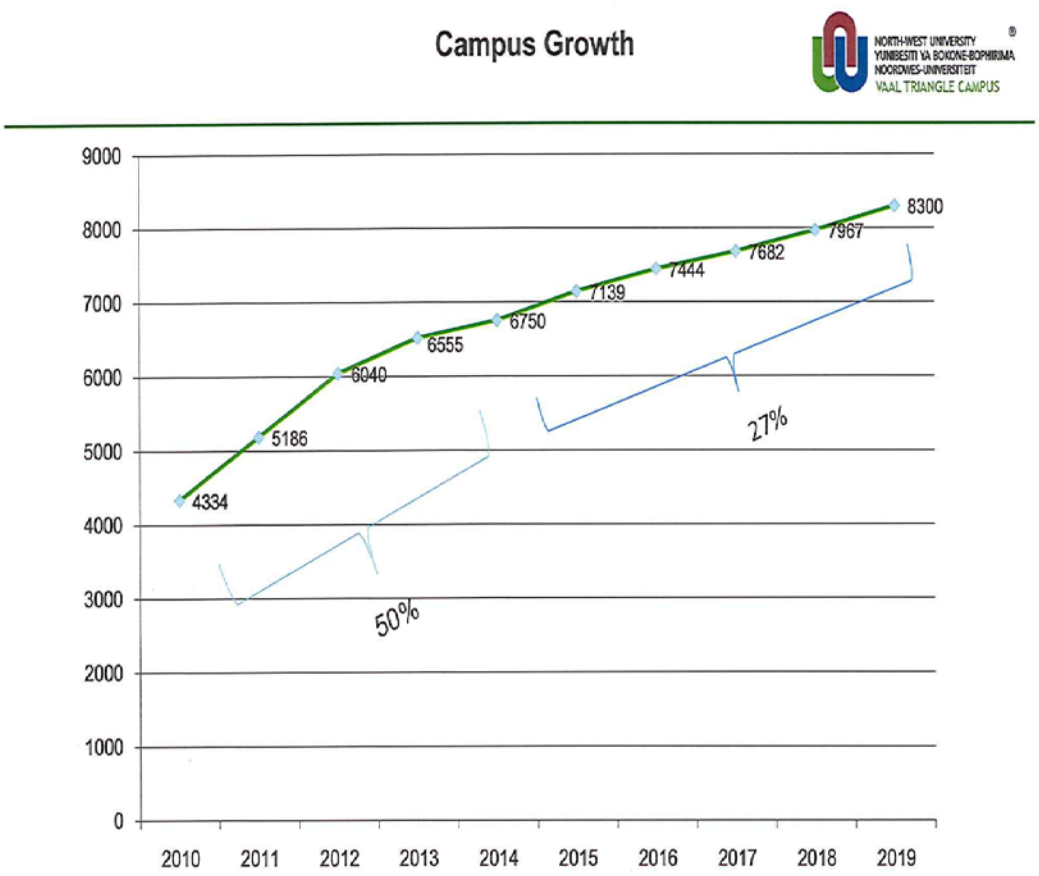
ANNEXURE D

Campus Plan up to 2020



ANNEXURE E

Campus growth map till 2020



ANNEXURE F

Evidence of control of invasive plant species

INSPEKSIE VAN NWU VAALDRIEHOEK KAMPUS TERREIN
(vir verklaarde onkruide)

Na deeglike ondersoek het ons die volgende bevind:

Neem asb kennis van die volgende:
Kategorie 1 plante moet verkieslik onmiddelik verwyder word.
Kategorie 2 plante mag met toestemming kommersieel verbou word in sekere areas.
Kategorie 3 plante hoef nie verwyder te word nie maar mag nie verder aangeplant word nie,verder moet daar toegesien word dat die plante nie verder versprei op die betrokke perseel nie.

1. Agave americana (garingboom) kat. 1
2.Casuarina cunninghamiana(kanfer boom) kat 2
3.Cinnamomum camphora vrygespreek in ons area
4.Eucalyptus soorte(bloekom) kat 2
5.Cortaderia selloana(pampas gras) kat 1.
6.Cotoneaster soorte kat 2
7.Datura(stinkblaar) kat 1
8.Fraxinus americana kat 2
9.Gleditsia triancanthos(honey locust) kat 2 voorgestel kat 1
10.Melia azederach(sering)kat 3 voorgestel kat 1
11.Morus alba(wit moerbei) kat 2
12.Pyracanta crenulata(vuurdoring) kat 2
13.Salix babylonica(wilgerboom) kat 2
14.Cestrum aurantiacum kat 1

My professionele opinie is soos volg:
Om toekomstige probleme te vermy sal ek alle sering bome vernietig al is dit op die stadium 'n kat 3 maar daar is voorgestel dat dit na kat 1 moet verskuif.

Die peule van die Gleditsia(honey locust) is gesog onder vee en wild maar die bome kan in die toekoms ernstig versprei as daar geen wild is om dit te beheer nie.

Die cestrum bos met geel blomme is besig om stadig te versprei (naby die grens tussen NWU en Riverspray.
Die beste is om die onkruid af te sny en Garlon 4 op die stamme te verf wat hulle sal doodmaak.

Dankie
Gerhard Steenkamp
vir Magic Garden Centre

ANNEXURE G

Diary of researcher on environmental management dissertation process

DATE	MEET WITH	OUTCOMES
04/02/2012	Send e- mails to relevant participants. Prof Tempelhoff: water research and expert on water management Mr Frans Basson: Director: Technical Services –NWU Vanderbijlpark Campus Mr Kobus Potgieter – Technical Services	Waiting for response
07/02/2012	Mr Kobus Potgieter	Discuss the biodiversity on campus.
08/02/2012	Prof Johann Tempelhoff	Discuss a possible dissertation topic. Advises me to attempt a case study; offer assistance by linking me with CEM – Bibi Bouwman and Corlia chapter cRoos. Willingness to aid as a co- study leader is expressed.
13/02/2012	Mrs Pauline Kuhne and Prof Piet Prinsloo	MrsKuhne is currently starting the archive for this university. Meet to inform her of my intentions – she stated to help with suitable resources if she finds relevant information.
21/02/2012	Formal meeting: Mr Frans Basson – Director: Technical Services Mrs Marietjie Saunders: Technical Services Mr Burger Scholtz: Food Services	During this meeting I share my intent to do research on environmental management of the campus. I focus on the necessity of a mind shift change, the input of different role players and most of all the support of top management. All were willing to support the initiative and is well aware of the benefit of such a plan that is already part of the total management plan of the university. Agreement to share information was reached. An open book policy between role players will guide all communication and planning. Prof Mariba, campus rector, was informed of the meeting and give consent to the dissertation.

DATE	MEET WITH	OUTCOMES
18/03/2013	Formal meeting: Frans Basson Marietjie Saunders	Give a list of possible people to contact regarding information. Agree on a documentation system for all environmental matter – situated at Magda Theron (Frans's secretary)
27/05/2013	Formal meeting: Frans Basson Marietjie Saunders	Issues from previous meetings were readdressed and information not available is again requested.
22/10/2013	Meeting with Burger Scholtz	Discussed wildlife and future plans regarding it.
07/11/2013	Field trip with MrJ. Strauss	Observe real practices on campus; take photos and asked questions
15/11/2013	Meeting with Prof Linda du Plessis	Discuss campus governance; future planning and student reactions related to environmental issues
23/11/2013	Informal meeting with Prof Tempelhoff	Indication of money available to invest in green initiatives; discuss possible position a student in green initiatives

ANNEXURE H

List of needed documentation as discussed in meeting with Technical Services (in Afrikaans)

DOKUMENTASIE BENODIG: IRENE MULLER

1. Kampus plan – area ondergeboue, parker terreine, oopvelde, damme; sport terrein en ontspanningsgebiedens.

   Geboue: Lesingslokale ; Ook die residensiële woning van studente op en af kampus; en Quest moet hierby ingesluit word.

   Die groenbiblioteek – relevanteinligting

2. Afval – enige inligting oor die proses; wanneer dit verwyder word; hoe dit verwyder word- dus skedule. Sluit ook in elektroniese afvalbestuur. Enige vorm van sortering van verskillende soorte.

3. Water bestuur op kampus – gebruik van rivier water en munisipale water. Water suiweringsprojekte op kampus/nie?

4. Energie bestuur en verbruik – verbruik en besparing in geboue

   Inligting: bv. indien die lugversorgers op tydsone gestel en beheer word; ligdetektors wat aan en afgaan met beweging op kampus snags? besparing in residensiële geboue – het die student riglyne wat hul by hou? Kompetisie tussen koshuise vir energie besparing? bewyse van besparing

5. Transport – die busvervoerstelsel (al is dit uitgekontrakteer – is besparend!) – enige inligting is welkom; die universiteit se eie motors – soos gholfkarretjie op kampus is belangrik vir besparing. Indien daar in die vloot hibried motors is – wat battery en elektrisiteit gebruik – nog beter. Hoeveel van die student ry met motors? – enige getalle beskikbaar?

6. Biodiversiteit

   Plante: die identifisering en beheer van indringerplante; soorte plante – indien geidentifiseer

Diere: getalle en beheer; moontlike migrasie patrone – bly in somer en winter op verskillende dele van kampus?

Enige inligting oor interaksie met mense – soos die mensewat met die boot gekom en ‘n bok geskiet het ? Is daar ooit enige bokke deur studente geneem?

Vis damme: ontstaan, tipevis; beheer van vis en toestand van vis.

Voëls – enige inligting gedokumenteer?

Indringers: Katte, apies – relevante dokumentasie

7. Ramp bestuur – noodplan en kampusveiligheid; rapportering van insidente wat kampus veiligheid bedreig? Vuur en weerlig – hoeveel brandblussers ,weerlig afleiers by relevante geboue.

8. Lug kwaliteit – enige bewyse van lug samestelling op kampus ?– die mis in die winter wat die gasse van nywerhede kondenseer moet ‘n rol speel. Die aantal motors op kampus speel hier ook ‘n rol.

9. Veiligheid van werkers en studente – moontlike planne vir ontruiming van geboue ens. Sluit aan by 7.

ANNEXURE I

Evidence of meeting with Technical Services

Vergadering – omgewingsbestuur 18 Maart 2013

1 Area ondergeboue - Marietjie Saunders vra P van Heerden

2 Plan Faranani – Marietjie Saunders vra P van Heerden

3 Plan Quest – Marietjie Saunders vra P van Heerden

4 Studentegetalle – vra by Neels I.M.

5 Personeelgetalle – vra by Elbie I.M.

6 Organisasiestruktuur – vanaf FB na I

7 Besparings – ditwat reeds gerealiseer is. FB na I

8 Toekomstigebesparings – I.M. E-posna FB

- vra vergadering met Joep.

9 Afvalbestuur - kan baie gedoen word.

- koswel in plek
- Buisligtekontrakteur
- Medies – in plek
- Bourommel – kontrakteur

10 Oudit – 17 nie voldoeningspunte

- Hou rekord van alles wat ons regstellend doen. Magda

11 Biblioteek – nie groen. Wel besparende elemente – Paul Greyfenstein.

12 Inligting oor NWU voertuie. A Herbst

13 Rampbestuur - Kobus/Chris

14 Busvervoer :Betsie Boshoff

15 Indringer plante : FB na |I.M.

ANNEXURE J

Interview with Burger Scholtz – Food services manager and in charge of wildlife

1. According to archives did the campus started in 1990 with 6 springbuck and 6 blesbuck. Is that correct?
No, according to me, the keeping of wild already started in the late 1980's. Yes we started with limited numbers.
2. What was the motivation after keeping wildlife on campus?
We decided to keep wildlife due to the availability of land and because it is peaceful and created a beautiful ambiance next to the river.
3. Do you have the numbers of wildlife in a register and may I have access to it?
Yes I do have a register, although it is not sorted. I know what is going on and you may have access to the register but I need to order it first.
4. Which types of wildlife was added? And how do you decide on which species to keep?
We had everything here from ostriches to zebra. The ostriches went into the parking areas and act hazardously when looking in the mirrors of motor cars for themselves. Kicking the cars etc. We had to let them go. Smaller species react better in the smaller environment. The wildebeest need to go – they run in groups of 10 which are too much and create a lot of erosion to the land by digging holes.
5. How do you control numbers?
We dart the excess wild with the aid of a veterinary surgeon and sell it.
6. How do you monitor the feeding coming from the veld?
The same way you monitor your groceries – we give extra nutrition in winter, during drought.
7. Did climate ever harm the wildlife? Like flooding? Lightning? What about veldfires?
We burn a buffer zone around the campus to prevent fire. Veld fires never occurred on campus. During flooding the wildlife move to higher ground.
8. Any incident with poachers? I remember in my time a situation where poacher came via the river?
Yes it did happen and we lost two buck, but it is not really harmful. Safety services help protect the wildlife.

9. Ever lost wildlife due to students?
I believe students often caught some geese, but they are many and we cannot exactly tell. Buck was never lost due to student action.
10. Does building projects affects wildlife?
Yes, the buck used to come to higher ground in the west at night. Building actions restricted their movements.
11. The Legal compliance audit of 2012 revealed: **Management of protected species:** The Vaal Triangle Campus of the NWU has historically and is still keeping a number of game species on the campus. These include springbok (51), blesbok (22), gemsbok (16) and black wildebeest (13). The black wildebeest has been declared as a protected species in terms of the National Environmental Management: Biodiversity Act (NEMBA) No. 10 of 2004. This species, together with gemsbok, has also been declared as protected game in the Transvaal Nature Conservation Ordinance No. 12 of 1983. The Transvaal Nature Conservation Ordinance No. 12 of 1983 regulates the keeping of live game, including protected game and requires that no person shall keep or convey live game, unless he is the holder of a permit which authourises him to do so. The National Environmental Management: Biodiversity Act (NEMBA) No. 10 of 2004 requires that a person may not carry out a restricted activity involving a specimen of a listed threatened or protected species without a permit issued in terms of Chapter 7. The act defines restricted activities in relation to a specimen of a listed threatened or protected species as gathering, collecting or plucking any specimen of a listed threatened or protected species; picking parts of, or cutting, chopping off, uprooting, damaging or destroying, any specimen of a listed threatened or protected species; having in possession or exercising physical control over any specimen of a listed threatened or protected species; growing, breeding or in any other way propagating any specimen of a listed threatened or protected species, or causing it to multiply; conveying, moving or otherwise trans-locating any specimen of a listed threatened or protected species; and selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or disposing of any specimen of a listed threatened or protected species. **Although evidence was found that the NWU Vaal Triangle Campus applied to the Gauteng Department of Agriculture, Conservation and Environment for a protected species permit for the black wildebeest in 2008, no evidence could be found that such a permit had been issued. No evidence could also not be found that a permit has been issued for the keeping of gemsbok and black wildebeest in terms of the Transvaal Nature Conservation Ordinance** Any feedback from the Department of Nature Conservation regarding this?
I handed all documentation over to the Institutional Office – I have no idea what is going on.

12. The man made dams – how do you monitor the fish?
Once a year a catch and release action is performed to establish the status of the fish. Size indicates if the fish have enough habitat and according to that we react.
13. I noticed a lot of the dams are polluted? Any influence on the fish?
Once it rained the streaming of dams occur naturally and the pollution is resolved. I do not think the fish is harmed.
14. There is concern from the personnel that the water watering the gardens harmed their cars. A white residue is left on cars after sprinkled with water from dams.
The harm is then coming directly from the river – the dams are filled from it.
15. What do you think is the greatest thread to biodiversity on campus?
The biodiversity is not harmed at this stage; there is enough available land and we need to keep to smaller species like bles and springbuck which adapted well in smaller areas. People?

ANNEXURE K

Interview with Prof Linda du Plessis (Vice rector, NWU (Vaal)

Interview with Prof Linda du Plessis – 15 November 2013

1. Do I have the correct idea regarding the governance structure of the NWU if I say the Institutional office is in control?
Yes, you have. But campuses are autonomous regarding how they initiate and use resources.
2. Did the incorporation of Vista in 2002 and the merger of 2004 change the student profile significantly?
Definitely, I will give you a document on head counts from 2000 to 2013 indicating the race and gender of student that display it properly. The merger and incorporation was a decision from national government.
3. I am concerned when I noticed the campus was built for 10 000 students. Will the campus character survive this influx of more students?
We are very concerned about the campus character and wildlife. Our growth plan predict about 8300 students in 2019 therefore less than foreseen. Our balance regarding research is totally out – we need more post grad students and aim for 30 %; currently we have like 12 %.
4. Am I correct if I say the management structure is a possible threshold?
I will supply you with a document from Stumph who did a study on the merging and institutional office. You will find in it relevant reasons why it can be true.
5. How much impact do students have on governance? I am aware that the student riots of 2013 were linked to environmental issues.
Yes, students use stoves as heaters and are angry when management stopped it. We also try to monitor energy consumption and have a good idea of the average energy a student need per day. They did not like the power boxes that regulate this. They also want us to put in extra gates so that they can easily walk across campus to the buildings from nearby neighbourhoods. We cannot let the students walk everywhere - that will harm biodiversity.
6. How green is management and planning?
We try to initiate green initiatives like planting trees; the new library has green elements like optimal use of daylight; paving is laid to aid with draining of rain water etc. We care about the campus character and want to preserve it. We made resources available to aid the green initiative.