Human Resources Indicators for Water Research in South Africa: Strategy for the Development of a Water Research Database of Theses in South Africa

Report to the
Water Research Commission

by

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Abbreviations

DBL – Doctor in Business Leadership
DST – Department of Science and Technology
D Ed – Doctor of Education
DTech – Doctor of Technology
HEMIS – Higher Education Information Management System
HRST – Human Resources in Science and Technology
LLD – Legum Doctor
MA – Master of Arts
MBA – Master of Business Administration
MEng – Master of Engineering
MSc – Master of Science
NRF – National Research Foundation
NSF – National Science Foundation
PhD – Post-Doctorates
R&D – Research and Development
S&E – Science and Engineering
S&T – Science and Technology
SANEDI – South African National Energy Development Institute
SIS – Science Indicator Systems
UNISA – University of South Africa
WRC – Water Research Commission

Executive Summary

This document has been prepared on the request of the Water Research Commission (WRC) in order to inform "The *Pulse Study on the State of Water R&D* in South Africa". The investigation is a first attempt to obtain a quantitative account of the production of post-graduate students related to water research in South Africa.

Water related research is a multidisciplinary activity and students can undertake relevant research in different academic departments which are not always directly related to water activities. For example, water related research can be performed in faculties of engineering, science; social sciences and so on. As such the identification of post-graduates working in the field of water is a challenging activity.

For the purposes of this investigation we developed a series of relevant descriptors and identified all masters and PhD theses awarded during the period 2000-2011 by the country's higher education institutions.

The findings, using the NEXUS database, show that there were awarded 250 PhDs and 1331 Masters of different types (e.g. MSc; MA, etc.) during the period. These figures are considered adequate for the South African reality. South Africa is producing a small number of post-graduate students in general and in comparison to the field of energy, another multidisciplinary field, the field of water produces four times as many post-graduate students. It is mentioned that all scientific disciplines produced 1380 PhDs during 2009 (according to HEMIS of the Department of Higher Education and Training)

The ranking of the country's higher education institutions according to the number of PhDs and/or Masters they produce exhibits variability because of the small number of post-graduates being produced. Content analysis further indicates that the theses emphasise local conditions and identify topics of focus.

The final chapter "Discussion and Recommendations" elaborates on the findings and advances the following recommendations:

- Monitoring the production of post-graduates is a critical issue in science, technology and innovation policy internationally and for South Africa in particular. The WRC, as the custodian of water related research, should consider developing a relevant database of PhD and Masters awarded by the country's higher education institutions. Such a

database will be useful for scientometric investigations and will be also a knowledge repository[1]

- The "Pulse Study" of the WRC has initiated and supported the collections of data related to science, technology and innovation policy in the country. These include research outputs; inventive statistics and in this report human resourced development. WRC should consider completing the relevant set of main indicators (e.g. including funding for water related research and development) and publish regularly a report describing the state of water research in South Africa. Such a document will provide valuable information to policy makers; researchers and relevant industry.
- The international literature related to indicators in general and human resources in particular provides guidance on policy issues that should be investigated further. For example, will those completing post-graduate studies related to water find employment? Do they remain in the water environment or move to other fields? What is the unemployment rate – short term and long term – of those post-graduates?
- The dispersion of research and the content analysis indicate a lack of research focus in the country. The WRC should consider undertaking some form of prioritization exercise (e.g. foresight) in order to guide the research community.
- The identified distributed presence of water research in the country has been identified also in previous investigations. The phenomenon may adversely affect productivity and economies of scale in the field. It will be important for the WRC to examine the issue further and take appropriate action (e.g. establish centers of expertise with critical mass of researchers in focus areas and similar).

[1] Other databases do not identify water related theses

Introduction

Monitoring and evaluating the various facets of the scientific enterprise is a necessary and integral part of program and policy development. Rising costs of research and development and competing disciplinary and programmatic claims for financial resources require intelligent allocation of resources, which presupposes knowledge of the activities and performance of the innovation system.

Disciplinary, programmatic, national and regional assessments (Pouris et al., 2014; Molatudi et al. (2009); Jeenah et al., 2008) based on quantitative indicators are used internationally in support of policy development. There is a growing awareness of the advantages of basing opinions and subsequent choices on criteria that lend themselves more to quantitative evaluation. Science policy reviews would seem inconceivable today without recourse to existing indicators. Disciplinary assessments are used as benchmarks for the identification of effectiveness of policy instruments, for the support and justification of funding to political authorities, for identification of international collaborators, centres of excellence and so on.

There is a multitude of users and uses of indicators.

Public policies whose purpose is to influence innovation, either directly or indirectly, include:

- R&D support programmes;
- corporate tax policy;
- intellectual property rights and antitrust enforcement;
- environmental and health and safety regulation;
- economic development programmes, etc.

Each policy domain has its own information requirements for uses ranging from programme impact analysis to the identification of technology trends in particular industries.

Furthermore, information on the chain from R&D to innovation informs government budget decisions regarding the allocation of funds in support of science and technology. To address the basic question of how much the government should spend on R&D and in what fields information is required on the benefits and costs of subsidising R&D and on the market failures

that justify government intervention. Private initiatives left to them will not produce socially optimal results.

In addition to meeting public policy information needs, science and technology data contribute to private corporate planning and benchmarking.

This multitude of users and uses of the S&T indicators and the consequent financial trade-offs have led to efforts to develop science indicator systems (SIS) consisting of prudently organised indicators.

The underlying rationale is that the development of indicators to be included in any SIS should reflect its purpose and the ways of intended usage.

In South Africa, monitoring and assessment have received particular attention recently and the government established the Department of Performance Monitoring and Assessment (DPME) in the Presidency in 2010 in order to ensure continuous improvement of service delivery through performance monitoring and evaluation.

Moreover, the WRC initiated the *Pulse Study on the State of Water R&D* in South Africa and is developing a system of indicators in order to obtain a quantitative account of key R&D trends in the sector. The system of indicators will also inform a larger WRC-led project that will function as the dedicated reporting mechanism and critical appraisal of water R&D trends in the country. The broader project will contribute to, and ultimately inform the sector's knowledge base on water R&D in South Africa and provide empirical material for additional research on policy, programmes, capacity, geographic spread and financing issues related to water R&D.

In the above context, a recent investigation (Pouris, 2013) reviewed the literature relevant to development of indicators and developed a set of indicators related to water research in South Africa. The study provided *output* indicators related to bibliometrics and patent analysis. Output indicators can be referred to as those indicators that are able to measure the outcomes of a system, whereas input indicators (e.g. Research funding) are those indicators that are needed to be inserted into a system in order to obtain the intended outcomes….

The investigation identified also two sets of additional *input* indicators that should be developed and be included in the "Pulse Study". The first set of data is related to human resources development. The report states: "It is important to monitor the number and direction of post-graduate students (masters and PhDs) in the field of water research. The WRC should

undertake the inclusion of such information in the “Pulse Study”. The second set of data refers to the identification of R&D expenditures in the field of water research and its relevant subcomponents.

This report develops and identifies the set of data related to human resources development in South Africa. More specifically the objectives of the investigation are as follows:

1. Develop time series (2000-2011) of the number of PhDs related to water environment awarded in South Africa.
2. Develop time series (2000-2011) of the number of Masters related to water environment awarded in South Africa.
3. Identify most prolific universities (according to the number of post-graduates) in the production of water PhDs and Masters during the period and changes in ranking.
4. Identify the types of post-graduate degrees awarded (e.g. MA; MBA; MEng; M Law).
5. Identify topics of Masters and PhD theses (e.g. hydrology; modelling, water economics) during the period.
6. Identify WRC involvement/support in the production of post-graduate students.

The following chapter elaborates on the methodology used in this investigation. The chapter “Water related human resources development in South Africa” describes the findings and the report ends with a conclusions section. The last chapter includes suggestions for further research.

Methodology

An important set of indicators are those classified under human resources in science and technology.

The term refers to the human resources actually or potentially devoted to the systematic generation, advancement, diffusion and application of scientific and technological knowledge or a specific branch of it.

Users of human resources devoted to science and technology data include policy-makers and analysts in government-related agencies, the private sector and academia. Availability of skills and planning for the higher education sector are addressed with the use of Human Resources in Science and Technology (HRST) data. The results are also used by employers in all sectors (education, industry, and government) to understand and predict trends in employment opportunities and salaries in Science and Engineering (S&E) fields for post-graduate holders and to evaluate the effectiveness of equal opportunity efforts (NSF a, b various years).

Guidelines for the collection of human resources devoted to R&D are provided in the document *The Measurement of Human Resources Devoted to S&T* (Canberra Manual, 1995). The guide identifies post-graduates as the main target for the development of indicators; provides relevant definitions and suggests methods for data collection.

An important set of such indicators are those focused on the production of Masters and PhDs by the higher education system. These indicators provide information about the supply of researchers, in particular scientific disciplines and specialities, the academic institutions producing the researchers and their specialities, and provide valuable information for policy planning. The Department of Higher Education and Training (DHET) collects statistics for all post-graduates graduating from the country's universities; South African National Energy Development Institute (SANEDI) has commissioned a number of studies identifying the production of energy post-graduates; and recently the Department of Science and Technology (DST) advertised a tender aiming at explaining the limited number of students following post-graduate studies in South Africa and others.

As we mentioned earlier identifying human resources involved in water related research and development is a challenging issue. The reason is that water related research is a multidisciplinary and interdisciplinary activity and researchers and relevant students can

undertake relevant research in different academic departments. For example, water related research – is **performed** in faculties of engineering, science; social sciences and so on.

There are 2 possible approaches to identify water related research. The first is to survey all post-graduates about the relevance of their research to water. The second approach is to search the titles of theses for their relevance to water. Such an approach requires the following:

- identification of the appropriate database to be utilized for the creation of the water research theses set
- development of a list of descriptors identifying water related research and
- development of a search strategy using the identified descriptors.

Databases with information related to theses and dissertations exist internationally. Examples include the Australasian Digital Theses Programme; the Theses Canada Portal; the Dissertations and Theses Full-text of the Library of Congress and others.

The database required for the objective of this effort would have to cover all South African universities; include completed Masters and PhD theses; cover the period that we are interested to investigate; contain bibliographic references and similar.

In South Africa, individual universities have their own databases e.g. UNISA Electronic Theses and Dissertations database. However, searching individual databases may provide additional complications. For example, the UNISA database covers theses and dissertations only since 2003.

A database that meets our requirements is the NRF NEXUS database. The "Current and Completed Research Projects" section of NEXUS includes South African dissertations and theses. It provides information on all fields of science since 1919. English titles are given for projects not in English. It also includes abstracts. A limited number of records contain links to the full-text.

The database has been created in order to:

- “Facilitate access to bibliographic information on grey literature e.g. dissertations, theses and research projects
- Assist students with the
  - Identification of gaps in a research field
  - Consultation of similar studies to assist with research methodology
  - Identification of recommended research included in the theses or dissertations that provides opportunities for further investigations
  - Evaluation and analysis of completed studies in order to arrive at new solutions, policies, etc. (Literature reviews)
- Provide information to identify experts in a specific field of study
- Stimulate research in neglected areas
- Encourage networking and collaboration between researchers
- Facilitate research capacity development
- Facilitate informed decision making and strategic management” (NRF, 2014)

The Advanced Search interface facilitates searching according to search terms and relationships between terms and phrases using Boolean and/or Proximity operators.

While the database has not been created in order to facilitate the identification of water theses it can facilitate such undertakings. It should be mentioned that most of the bibliometric indicators used for indicator development were not created for that purpose.

For the identification of water related theses in the database we employ approaches used in bibliometrics.

Bibliometrics is a useful tool to map the literature contributing to a research field. The approach has been used in many global studies of specific fields. It refers to the research methodology employed in library and information sciences, which utilizes quantitative analysis and statistics to describe distribution patterns of articles within a given topic, field, institution, country and/or in the world.

The delineation of a research field is dependent on the identification of relevant descriptors. For this purpose previous relevant studies and expert opinions are utilized. A literature review identified a number of relevant studies (Fu et al., 2013; Wang et al., 2010; Hu et al., 2010; Ho 2008; Vertrees, 1985) from which we were able to extract relevant descriptors. Similarly, we

identified classifications and relevant descriptors used in the water research literature e.g. Water Resources Abstracts.

Table 1 lists the set of descriptors identified. It should be emphasised that these types of investigations have to balance two types of errors – to include records that are not supposed to be part of the set or to miss records. We aim to err towards the former as the number of expected outputs could be cleaned further manually after their identification.

Table 1: Descriptors: Search Terms

adsorption
Aqua*
Aque*
Aquifer
Arid
Artificial + recharge
Basin*
Bioaccumulation
Biosorption
Borehole
Canal
Catchm*
Dam
Desalination
Drain
Dredg*
Drought
eutrophication
Effluent
Estuar*
Evaporat*
Flood*
Frost
Hydrau*
Hydro*
Ice
Irrigat*
Lake*
Limnolog*
Marine
Micropollut*

Pipe*
Precipitat*
Rain*
Riparian
River*
Runoff*
Salin*
Sanitation
Sediment*
Seepag*
Sludge
Snow
Stream*
Tidal
Toilet
Waste*
Water*
*Water
Water
Wetland
Well

The descriptors were used in order to identify relevant theses in the database. The advanced search interface in NEXUS facilitates searching according to search terms and relationships between terms and phrases using boolean and/or proximity operators. For the objectives of this investigation we identified all theses and dissertations with at least one of the descriptors in the title. Furthermore, we made sure that the titles correspond to a completed thesis or dissertation for the period under investigation. The resultant list of theses and dissertations was investigated manually in order to confirm that the particular document belongs to the field of water research.

Water related human resources development in South Africa.

Figure 1 shows the number of water related PhDs awarded per year. During the 12-year period, 250 PhDs or similar were awarded. PhDs were the majority of the relevant qualifications (220). DPhil were 11; DTech 7 and DEng 6. There was one in each of the following categories: LLD; DEd; DCom; DBL and DAdmin.

The figure further shows that there was a decline in the number of PhDs in the second half of the decade. During the 2000-2005 period the universities produced 126 PhDs. During the second 6-year period 96 PhDs were awarded. It will be interesting to investigate the reasons for this decline.

Table 2 shows the awards per year and institution. It should be emphasised that a number of universities were merged after 2004

Figure 2 shows the number of PhDs awarded from the various institutions during the 12-year period. On top of the list are the University of Free State; University of Pretoria; University of Cape Town and Rhodes University. Each university produced approximately 2.5 PhDs per year over the period. This is a relatively small number and indicates the lack of concentration of water research in South Africa. Researchers and PhD candidates are distributed across the whole country.

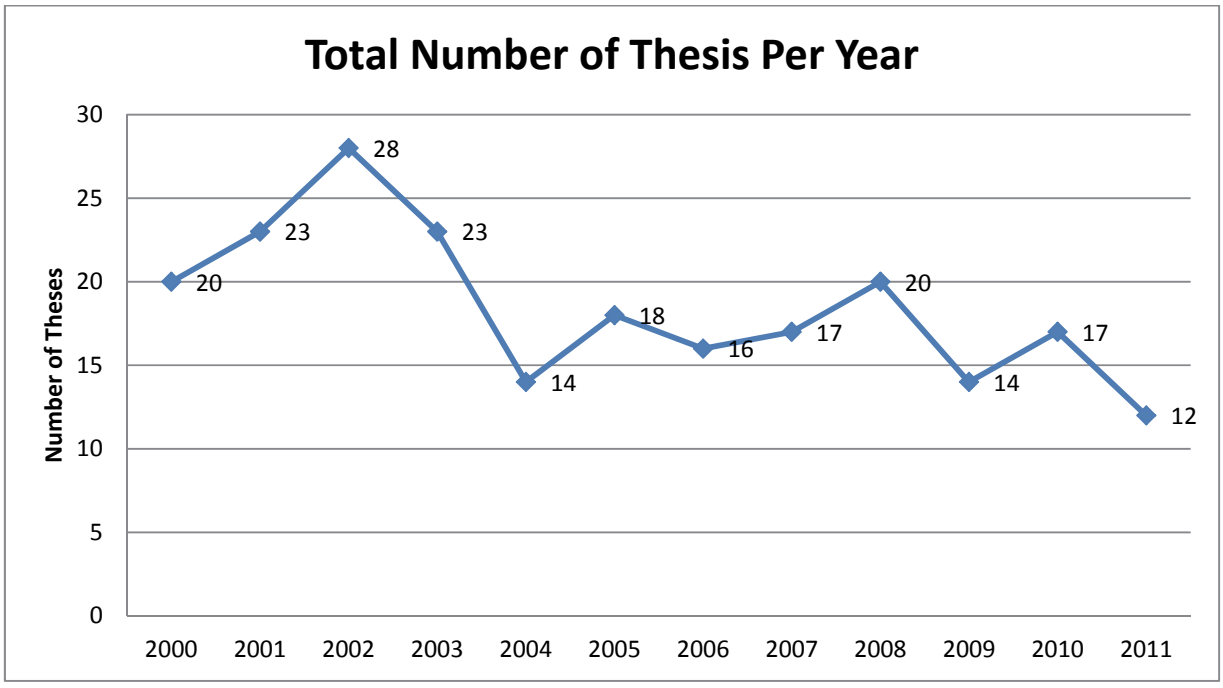

Figure 1: Number of PhDs Awarded Per Year

Table 2: PhDs Awarded Per Year and Institution

PhDs per Year per University													
	Year												
Universities	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
University of Pretoria	3	3	2	0	2	4	4	4	2	3	2	2	31
University of Free State	2	0	3	4	2	2	0	5	8	1	2	1	30
Rhodes University	2	2	3	3	0	2	3	2	0	2	5	4	28
University of Cape Town	3	2	3	2	2	6	3	2	0	2	2	1	28
University of Western Cape	0	0	2	3	2	1	2	1	4	3	2	3	23
Witwatersrand University	2	5	3	2	2	2	2	0	2	2	0	0	22
Stellenbosch University	0	1	1	2	2	3	2	0	0	0	3	0	14
North-West University	0	0	0	0	2	0	0	0	2	1	2	4	11
Rand Afrikaans University	1	0	6	2	0	0	0	0	0	0	0	0	9
University of Port Elizabeth	4	1	2	2	0	0	0	0	0	0	0	0	9
University of Natal	1	1	3	3	0	0	0	0	0	0	0	0	8
University of KwaZulu-Natal	0	0	0	0	0	0	1	3	0	0	2	0	6
Potchefstroom University for Christian Higher Education	0	3	1	1	0	0	0	0	0	0	0	0	5
Technikon of Free State	1	4	0	0	0	0	0	0	0	0	0	0	5
Nelson Mandela Metropolitan University	0	0	0	0	0	2	0	0	1	0	0	0	3
Tshwane University of Technology	0	0	0	0	0	0	0	0	2	0	0	1	3
University of Fort Hare	0	0	0	1	0	0	0	0	0	0	1	1	3
University of Durban-Westville	0	1	1	0	0	0	0	0	0	0	0	0	2
University of South Africa	0	0	1	0	0	0	0	1	0	0	0	0	2
University of Zululand	1	0	0	1	0	0	0	0	0	0	0	0	2
Cape Technikon	0	0	0	1	0	0	0	0	0	0	0	0	1
Technikon Pretoria	0	0	1	0	0	0	0	0	0	0	0	0	1
University of Johannesburg	0	0	0	0	0	0	0	0	0	1	0	0	1
University of Limpopo	0	0	0	0	0	0	0	0	0	1	0	0	1
University of the North	1	0	0	0	0	0	0	0	0	0	0	0	1
Vaal Triangle Technikon	0	0	0	0	0	1	0	0	0	0	0	0	1
Total	**21**	**23**	**32**	**27**	**14**	**23**	**17**	**18**	**21**	**16**	**21**	**17**	**250**

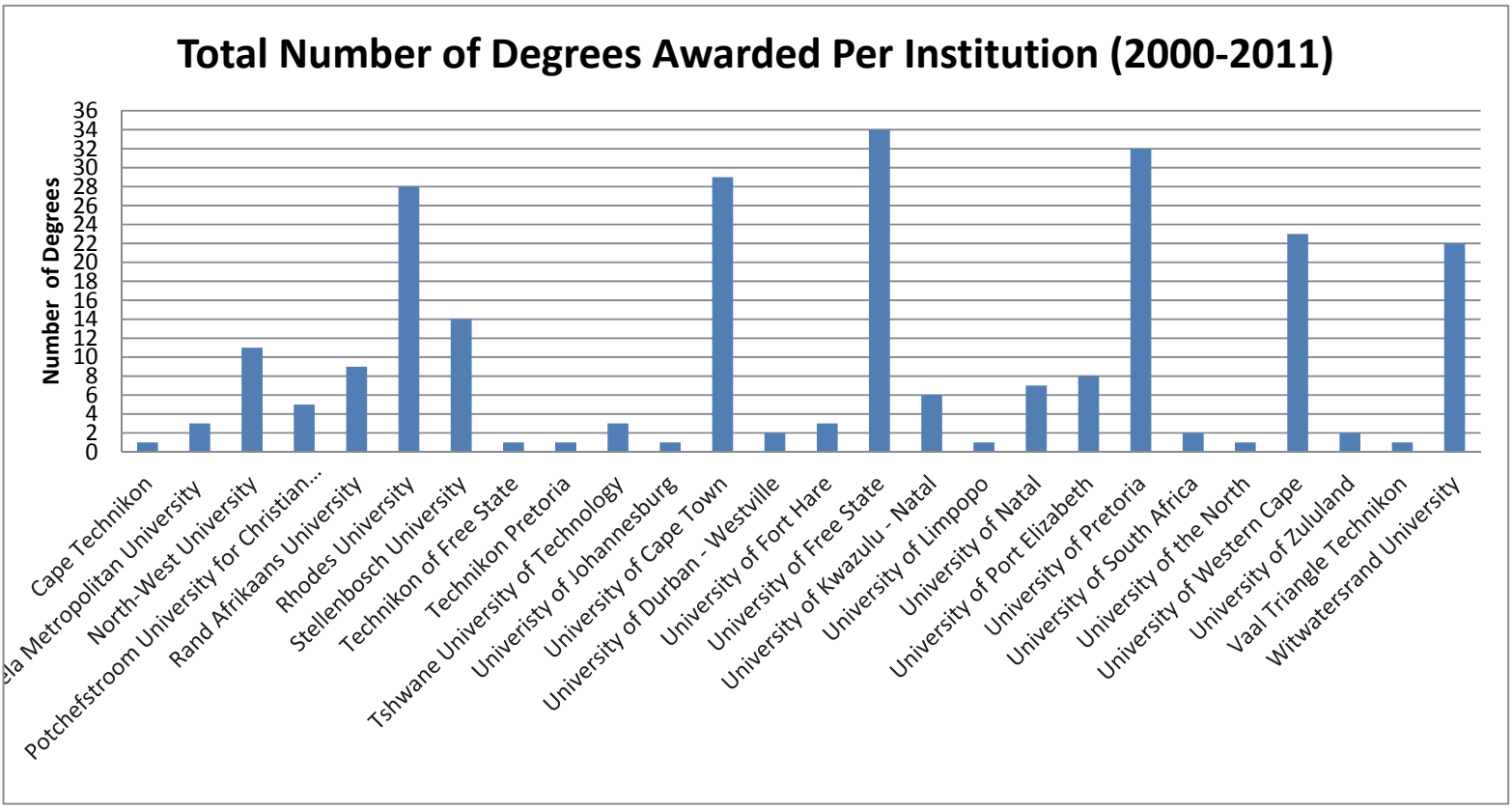

Figure 2: Number of PhDs Awarded Per Institution (2000-2011)

Tables 3 and 4 show the number of PhDs awarded by the various institutions over the 2000-2005 and 2006-11 periods. The University of Pretoria, University of Cape Town; Rhodes University and University of Free State appear on top of the list in both periods.

Table 3: Number of PhDs produced by various Universities over the period 2000-05

PhDs Per University	
	Year
Universities	**2000-2005**
University of Cape Town	18
Witwatersrand University	16
University of Pretoria	14
University of Free State	13
Rhodes University	12
Rand Afrikaans University	9
University of Port Elizabeth	9
Stellenbosch University	9
University of Natal	8
University of Western Cape	8
Potchefstroom University for Christian Higher Education	5
Technikon of Free State	5
Nelson Mandela Metropolitan University	2
North-West University	2
University of Durban-Westville	2
University of Zululand	2
Cape Technikon	1
Technikon Pretoria	1
University of Fort Hare	1
University of South Africa	1
University of the North	1
Vaal Triangle Technikon	1
Tshwane University of Technology	0
University of Johannesburg	0
University of KwaZulu-Natal	0
University of Limpopo	0
Total	**140**

Table 4: Number of PhDs produced by various Universities over the period 2006-11

PhDs Per University	
	Year
Universities	**2006-2011**
University of Pretoria	17
University of Free State	17
University of Western Cape	15
University of Cape Town	10
Rhodes University	16
North-West University	9
University of KwaZulu-Natal	6
Witwatersrand University	6
Stellenbosch University	5
Tshwane University of Technology	3
University of Fort Hare	2
Nelson Mandela Metropolitan University	1
University of Johannesburg	1
University of Limpopo	1
University of South Africa	1
University of Zululand	0
Total	**110**

Table 5: Frequency and Top Words in PhD Titles

Word	Occurrences
water	121
south	71
Africa	46
development	26
river	26
African	21
marine	16
case	15
groundwater	15
management	14
study	14
modelling	13
quality	13
using	13
irrigation	12
southern	12
environmental	12
system	12
analysis	12
selected	11
treatment	11
evaluation	11
rainfall	11
systems	10
eastern	10
cape	10
use	10
systems	9
impact	9

We used a text analyzer in order to identify the frequency of the various words in the titles of the theses. There were 2476 words in the identified titles. The word “water” is the most frequent

word as it was expected. The table is instructive in providing comparative statistics. For example, the word “river” appears almost twice more often in the titles than the words “marine” or “groundwater”. Similarly the word “rainfall” has a lower frequency that the previous mentioned words.

Analysis of the frequency of two words phrases shows the most frequent phrase is “South Africa” (41 counts) indicating the localization of research. The phrase “water quality” appears 11 times and “case study” 10 times.

Figure 3 shows the number of Masters degrees awarded per year in the field of water. Approximately 111 degrees are awarded per year. During the 12 year period there were awarded 1331 relevant degrees. The majority of the degrees 739 (55%) were MSc. MAs were 173 (13%); MTech. 92; MEng 53; MEd 15; MBAs 46 and MCom 32.

The figure further shows that there was a decline in the number of Masters in the second half of the decade. During the 2000-2005 period the universities produced 743 Masters. During the second 6 year period awarded 588 Masters.

Table 6 shows the awards per year and institution. Figure 3 shows the number of PhDs awarded from the various institutions during the 12 year period. On top of the list are the University of Witwatersrand, University of Stellenbosch, University of North-West and University of Pretoria. Each university produced approximately 10 Masters per year over the period. This is a relatively small number and indicates the lack of concentration of water research in South Africa. Researchers and Master candidates are distributed across the whole country.

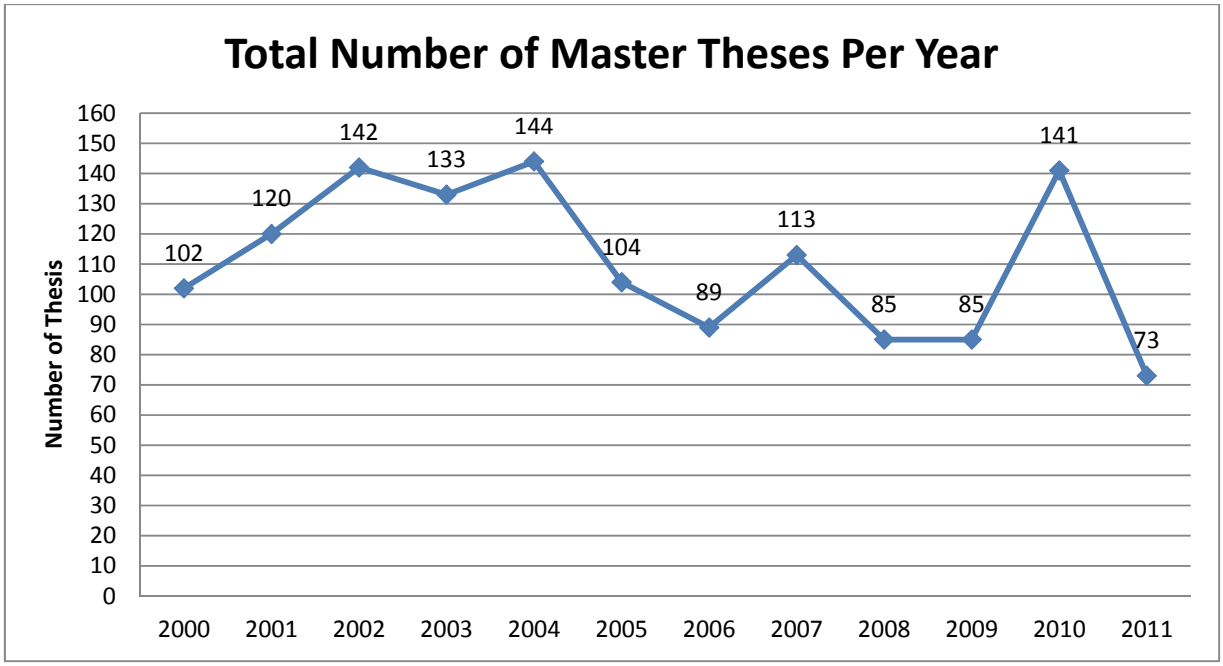

Figure 3: Number of Masters Awarded Per Year

Table 6: Masters Awarded Per Year and Institution

Masters per year per university analysis													
	Year												
Universities	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
University of Witwatersrand	8	13	11	18	21	11	8	13	15	4	10	5	**137**
Stellenbosch University	17	14	18	12	18	10	10	13	3	0	0	0	**115**
University of North-West	1	1	4	9	15	12	3	11	15	11	16	17	**115**
University of Pretoria	15	16	13	6	13	6	8	6	11	3	5	1	**103**
University of Western Cape	1	5	8	7	17	7	7	11	6	8	15	9	**101**
Rhodes University	9	7	7	7	12	9	6	2	1	7	18	9	**94**
University of Cape Town	9	1	0	0	0	24	5	15	0	9	19	7	**89**
University of Natal	10	14	36	27	0	0	0	0	0	0	0	0	**87**
University of KwaZulu-Natal	0	0	0	1	11	2	24	11	0	0	15	0	**64**
University of Johannesburg	0	0	1	0	8	4	7	7	10	13	3	0	**53**
University of Free State	3	3	0	13	4	6	2	1	3	3	4	8	**50**
Rand Afrikaans University	8	11	13	1	0	0	0	0	0	0	0	0	**33**
University of South Africa	2	3	0	2	1	2	0	4	3	8	6	0	**31**
Nelson Mandela Metropolitan University	0	0	0	1	2	4	3	4	2	5	8	1	**30**
Potchefstroom University for Christian Higher Education	7	8	11	4	0	0	0	0	0	0	0	0	**30**
University of Fort Hare	2	0	2	2	1	0	0	0	7	0	8	5	**27**
University of Limpopo	0	0	0	0	0	0	1	5	5	4	5	5	**25**
Tshwane University of Technology	0	0	0	0	0	2	1	3	2	4	6	4	**22**
University of Port Elizabeth	5	4	1	4	8	0	0	0	0	0	0	0	**22**
University of Zululand	0	2	4	2	3	0	2	3	0	0	0	2	**18**
Cape Peninsula University of Technology	0	0	0	1	0	1	0	1	1	4	3	0	**11**
Milpark Business School	1	0	6	0	0	2	1	0	0	0	0	0	**10**
Central University of Technology, Free State	0	1	0	1	4	0	0	0	1	2	0	0	**9**
Durban Institute of Technology	0	0	0	5	0	1	1	1	0	0	0	0	**8**
Technikon of Natal	0	7	0	0	0	0	0	0	0	0	0	0	**7**
Technikon Pretoria	0	3	1	2	0	0	0	0	0	0	0	0	**6**
University of the North	0	3	1	0	2	0	0	0	0	0	0	0	**6**

Cape Technikon	0	2	0	1	2	0	0	0	0	0	0	0	**5**
University of Venda	0	0	0	3	1	1	0	0	0	0	0	0	**5**
Technikon of Free State	2	0	0	2	0	0	0	0	0	0	0	0	**4**
University of Durban-Westville	1	2	0	1	0	0	0	0	0	0	0	0	**4**
Medical University of Southern Africa	0	0	2	1	0	0	0	0	0	0	0	0	**3**
Technikon of Port Elizabeth	0	0	3	0	0	0	0	0	0	0	0	0	**3**
ML Sultan Technikon	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Peninsula Technikon	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Vaal Triangle Technikon	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Da Vinci Institute for Technology Management	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Total	**102**	**120**	**142**	**133**	**144**	**104**	**89**	**113**	**85**	**85**	**141**	**73**	**1331**

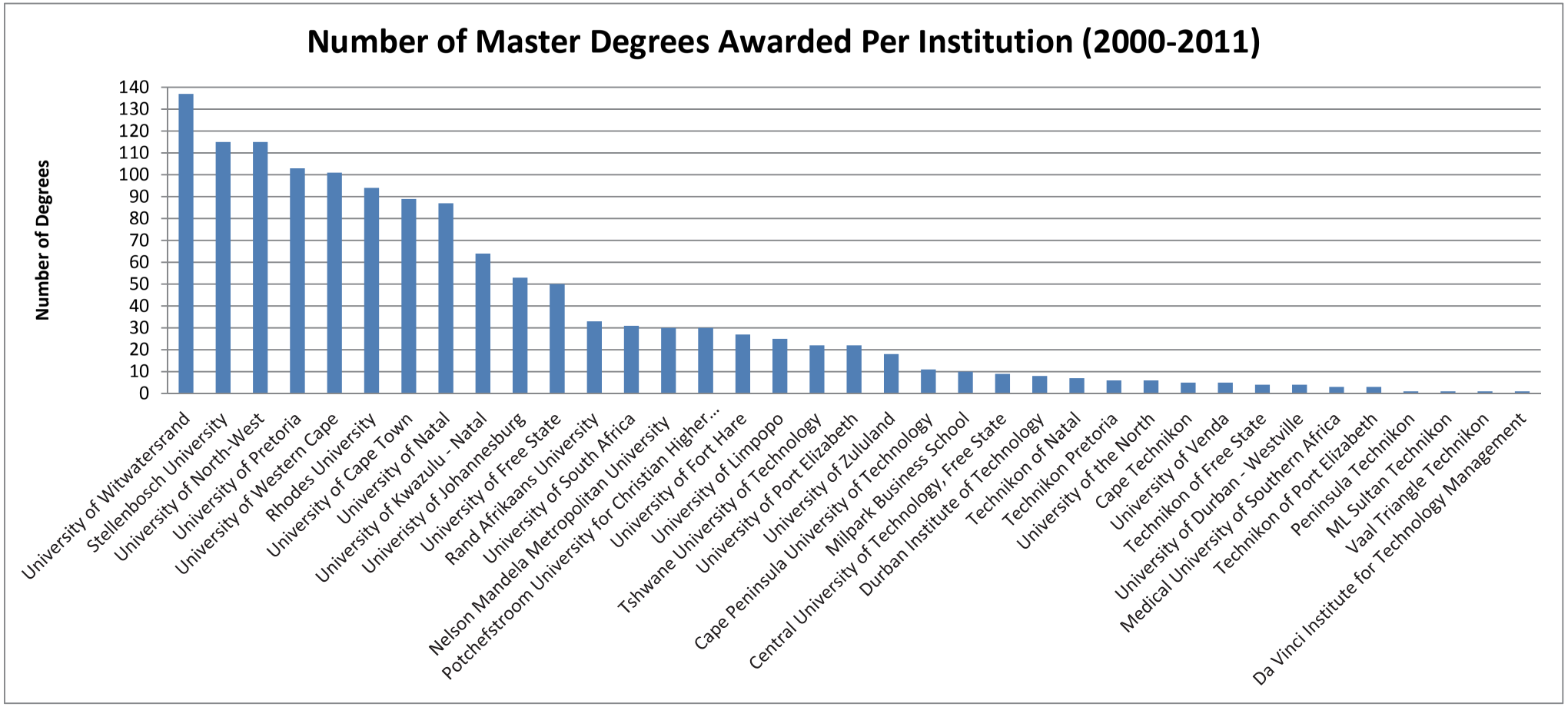

Figure 4: Number of Masters awarded Per Institution (2000-2011)

Tables 7 and 8 show the number of Masters awarded by the various institutions over the 2000-2005 and 2006-11 periods. University of Stellenbosch, University of Natal, University of Witwatersrand and University of Pretoria were the top institutions from 2000-2005. University of North-West, University of Western Cape, University of Witwatersrand and University of Cape Town were the top institution from 2006-2011.

Table 7: Number of Masters produced by various universities 2000-05

Masters Per University	
Universities	**Year**
	2000-2005
Stellenbosch University	89
University of Natal	87
University of Witwatersrand	82
University of Pretoria	69
Rhodes University	51
University of Western Cape	45
University of North-West	42
University of Cape Town	34
Rand Afrikaans University	33
Potchefstroom University for Christian Higher Education	30
University of Free State	29
University of Port Elizabeth	22
University of KwaZulu-Natal	14
University of Johannesburg	13
University of Zululand	11
University of South Africa	10
Milpark Business School	9
Nelson Mandela Metropolitan University	7
Technikon of Natal	7
University of Fort Hare	7
Central University of Technology, Free State	6
Durban Institute of Technology	6
Technikon Pretoria	6
University of the North	6
Cape Technikon	5
University of Venda	5
Technikon of Free State	4
University of Durban-Westville	4
Medical University of Southern Africa	3
Technikon of Port Elizabeth	3
Tshwane University of Technology	2
Cape Peninsula University of Technology	2
Peninsula Technikon	1
ML Sultan Technikon	1
University of Limpopo	0
Vaal Triangle Technikon	0
Da Vinci Institute for Technology Management	0

Table 8: Number of Masters produced by various universities 2006-11

Masters Per University	
Universities	**Year**
	2006-2011
University of North-West	73
University of Western Cape	56
University of Witwatersrand	55
University of Cape Town	55
University of KwaZulu-Natal	50
Rhodes University	43
University of Johannesburg	42
University of Pretoria	34
Stellenbosch University	26
University of Limpopo	25
Nelson Mandela Metropolitan University	23
University of Free State	21
University of South Africa	21
University of Fort Hare	20
Tshwane University of Technology	20
Cape Peninsula University of Technology	9
University of Zululand	7
Central University of Technology, Free State	3
Durban Institute of Technology	2
Vaal Triangle Technikon	1
University of Venda	0

Table 9: Frequency and Top Words in Master Titles

Word	Occurrences
water	558
south	255
Africa	146
management	130
river	115
case	96
study	92
marine	85
cape	84
being	82
quality	79
assessment	70
African	70
evaluation	66
development	65
impact	63
using	61
use	57
eastern	55
analysis	54
rural	51
groundwater	49
treatment	47
waste	46
irrigation	45
environmental	44
effect	43
investigation	43

We used a text analyzer in order to identify the frequency of the various words in the titles of the theses. There were 13 996 words in the identified titles. The word “water” is the most frequent word as it was expected. The table is instructive in providing comparative statistics. For example, the word “river” appears more than twice as often in the titles than the words “groundwater” or “waste”.

An analysis of the frequency of two-word phrases shows the most frequent phrase is “South Africa” (143 counts) indicating the localization of research. The phrase “water quality” appears 61 times and “case study” 61 times.

We attempted also to identify the WRC involvement in human resources development. The WRC does not provide bursaries but encourages researchers to involve post-graduate students in their investigation.

We were provided with data from the WRC’s Fund Management System. The system was set up in 2007 and hence data for 2007 and 2008 are minimal. WRC keeps relevant data in manual forms pre-2008.

Figure 5 shows the number of students that participated in the WRC projects. During 2010/11 there were more than 150 PhD students and 200 Masters participating in WRC projects.

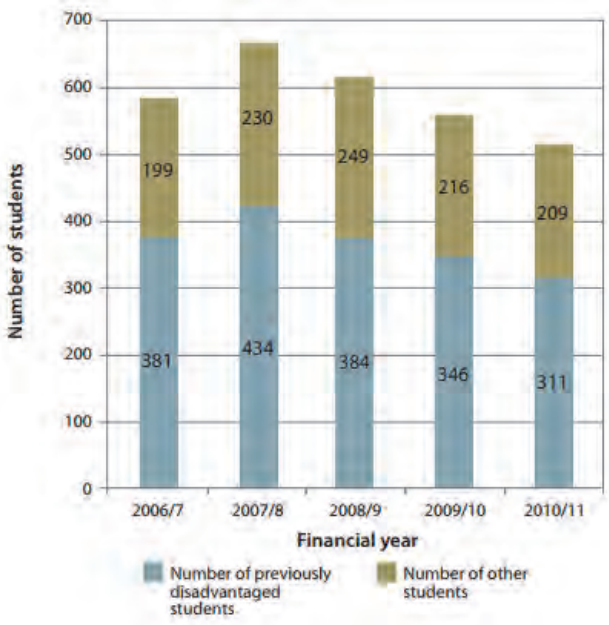

Figure 5: Number of students participating in WRC projects (WRC Annual report 2010/11)

Figure 6 shows the distribution of PhD candidates to various universities. The University of KwaZulu-Natal (23%) appears on top of the list followed by the University of Pretoria (14%) and the University of Cape Town (13%).

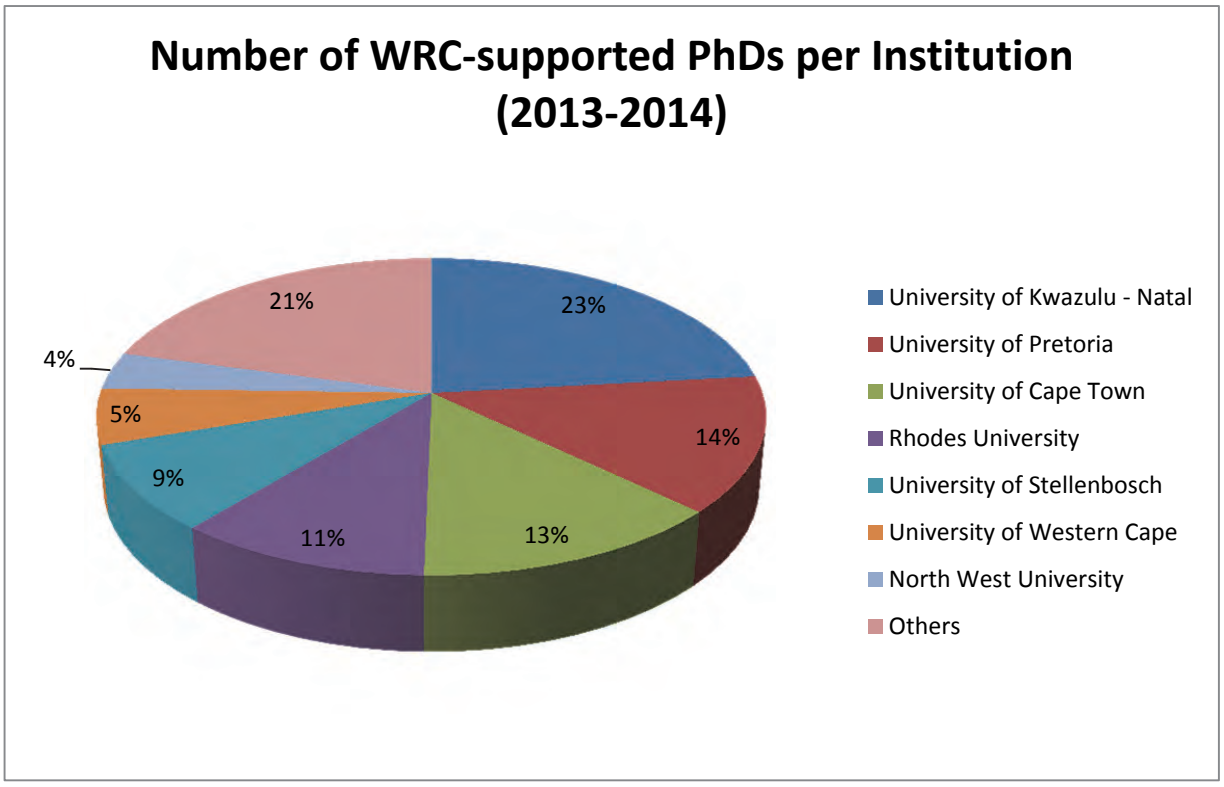

Figure 6: Distribution of PhD students participating in WRC projects to Universities (2013-14)

Figure 6 shows the distribution of masters students to various universities. The top four institutions are University of KwaZulu-Natal; Rhodes University; University of Pretoria and University of Cape Town.

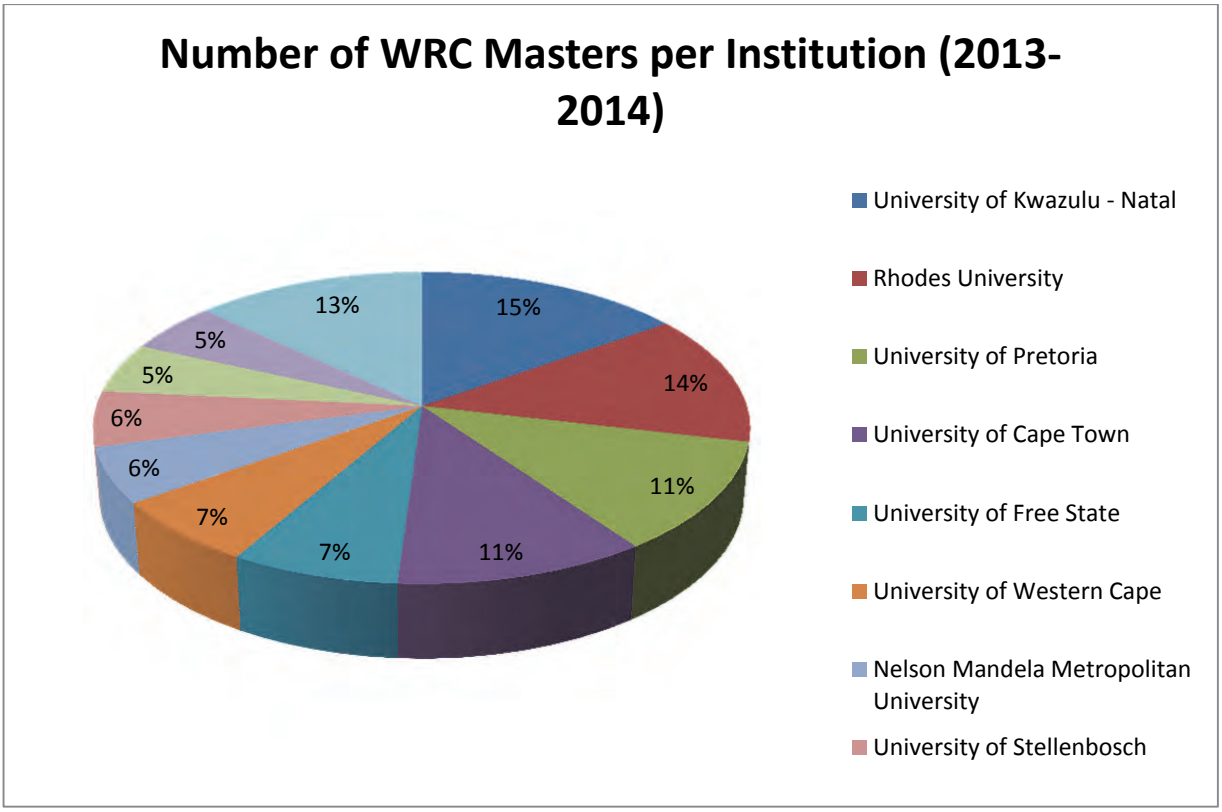

Figure 7: Distribution of Master students participating in WRC projects to Universities (2013-14)

It should be emphasized that these statistics are not compatible with the information from the NEXUS database. The “students” participating in WRC projects may do their academic research in fields that are not related to water; they may not have finished their studies and so on. In any case however, the candidates get expertise in the field of water research. The NEXUS data used on this investigation provides information only of students who completed their studies successfully on a water related topic.

Conclusions and Recommendations

This investigation set the objective to develop and identify the set of data revealing the state of production of post-graduate human resources in South Africa. Such statistics are valuable for science, technology and innovation policy development and are collected by relevant authorities internationally.

Water related research is a multidisciplinary and interdisciplinary field. As such, it faces challenges in terms of classification and identification of researchers and post-graduate students involved on the field.

For the purposes of this investigation we utilised the NEXUS database of the National Research Foundation and through the development of relevant descriptors we identified all masters and PhD theses awarded during the period 2000-2011 by the country's higher education institutions. The findings show that there were awarded 250 PhDs and 1331 masters of different types (e.g. MSc; MA, etc.) during the period. These figures could be considered adequate for the South African reality. South Africa is producing a small number of post-graduate students in general (1380 PhDs during 2009) and in comparison to the field of energy – another multidisciplinary field – the field of water produces four times as many post-graduate students (Pouris, 2010).

Identification of the institutions producing post-graduates in the field of water research shows the list of the institutions. The relevant ranking of universities varies over different time periods mainly because of the small number of post-graduates produced. An additional finding is that the country's universities produce individually small number of post-graduate students. The top universities in the country produce on average two to three water-related PhDs per year. This finding of small research size coincides with the findings from the investigation of research outputs. Research capacity in South Africa is distributed to various institutions precluding the creation of critical mass and economies of scale. It will be of importance to identify where those PhDs found employment and their relevant opinions. Such investigations are "good practice" internationally and they have the potential to guide science policy.

Text analysis provides comparative statistics. For example, the word "river" appears almost twice more often in the titles of PhDs than the words "marine" or "groundwater". Similarly the word "rainfall" has a lower frequency that the previous mentioned words. Analysis of the

frequency of two-word phrases shows the most frequent phrase is “South Africa” (41 counts) indicating the localization of water research.

Finally we investigated the support provided by the WRC for human resources development. WRC does not provide direct bursaries to post-graduates but the researchers funded by WRC utilize the services of post-graduates. WRC researchers declared that they involved above 150 prospective PhDs and 200 Masters during the most recent period for which data is available

A number of possible recommendations accrue from the above:

- Monitoring the production of post-graduates is critical issue in science, technology and innovation policy internationally in general and for South Africa in particular. The WRC as the custodian of water related research should consider developing a relevant database of PhD and Masters awarded by the country’s higher education institutions. Such a database will be useful for scientometric investigations and will also be a knowledge repository.
- The “Pulse Study” of the WRC has initiated and supported the collections of data related to science, technology and innovation policy in the country. These include research outputs; inventive statistics and in this report human resourced development. WRC should consider completing the relevant set of main indicators (e.g. including funding for water related research and development) and publish regularly a report describing the state of water research in South Africa. Such a document will provide valuable information to policy makers; researchers and relevant industry.
- The international literature related to indicators in general and human resources in particular provides guidance on policy issues that should be investigated further. For example, where those completing post-graduate studies related to water find employment? Do they remain in the water environment or move to other fields? What is the unemployment rate – short term and long term – of those post-graduates? And others.
- The dispersion of research and the content analysis indicate a lack of research focus in the country. The WRC should consider undertaking some form of prioritization exercise (e.g. foresight) in order to guide the research community.
- The identified distributed presence of water research in the country has been identified also in previous investigations. The phenomenon may affect adversely productivity and economies of scale in the field. It will be important for WRC to examine the issue further

and take appropriate action (e.g. establish centers of expertise with critical mass of researchers in focus areas and similar).

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