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What one knows is unknown to others: A Sediment Transport Study and its Policy Application

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The uptake of scientific knowledge is not always a grand affair. Many observers assume that scientists need to communicate with high-ranking government officials to influence policy. Grandiosely seen, scientists' views and understandings are utilised by government officials to change a national, provincial, or local government policy. Scientists can also communicate scientific knowledge with government officials in a 'low-key' manner where public administrators are not at the top of the governmental hierarchy. This paper reports on a dialogue between scientists from the Council for Scientific and Industrial Research (CSIR) and officials from the South African Department of Water and Sanitation (DWS) regarding a sediment research project in the Olifants River, South Africa. One of our results is that how scientists view the policy environment could have a bearing on the nature of their initiatives to develop uptake strategies. A view that exclusively highlights governments as policy actors could inevitably exclude non-state actors and vice versa.

Keywords: Sediment transport; Olifants River Basin; policy; uptake strategy; mutual learning.

1. Introduction

Scientists from the Council for Scientific and Industrial Research's (CSIR) Water Ecosystems and Human Health research group approached social scientists in the CSIR's Water Governance research group to develop an uptake strategy for a soil erosion study in the Olifants River basin, South Africa. The strategy's intent is to connect the research findings to stakeholders' needs (Funke & Nortje, 2012). Stakeholders can ask scientists what their research can do for the decision maker (Personal communication, K. Nortje, November 13, 2012). Regarding this, sediment transport in rivers is a poorly monitored phenomenon. Because of this scientific gap, and the inherent uncertainty that follows, it is necessary to

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study how scientists can interact with decision makers in a meaningful manner to increase the relevance of their research.[1] Because government officials can ask scientists about the relevance of their research and uncertainties around sediment transport, we indicate that scientists no longer do research for its own sake. Research has to translate into something practical that is useful to practitioners working with decision support systems. This paper reports on the uptake of the study by decision makers in South Africa's Department of Water and Sanitation's (DWS) Resource Quality Information Services (RQIS) Directorate. In this paper, public awareness does not entail awareness of the public at large, but more specifically for South Africa's water practitioners.

Throughout the manuscript, we will refer to decision makers as opposed to policy makers so that we do not discriminate between government officials and employees in the private sector and parastatals. Using the concept 'decision makers', is also an attempt to create a sense among scientists that their 'customers' are not *only* government officials but non-state actors too. It is, after all, not only government officials that formulate and implement societal policies, and, by default influencing society (Burns, Audouin, & Weaver, 2006). The purpose of this paper is to report on an interactive session between CSIR scientists and RQIS officials to discuss the findings of the CSIR's sediment transport study for policy purposes. We decided to engage RQIS officials, of which five attended the meeting, because this Directorate deals directly with water quality matters, including sediment transported pollutants. What is more, according to literature, soil erosion and sediments received more attention by scientists since the mid-1990s than before. Interest in general environmental problems, and European soil erosion policies (Verstraeten et al., 2003), elevated sediment's low profile in the scientific community. Sediment monitoring, through sediment yield data can, furthermore, be an important element in water resources management and soil conservation policies (Haregeweyn, 2006). For the policy community to take sediment and their associated pollution into consideration, require not only scientific measures and proper conceptualisation, but also linkages to population and community responses to support decision-making and addressing uncertainty (Chapman, Ho, Munns, Solomon, & Weinstein, 2002). Sediment and their role in aquatic environments still seem to be under-emphasised by water policy regulators and water authorities. This is not everywhere the case, with European countries taking the lead in including sediment issues in water policies. According to Förstner and Salomons (2010), the German *Flussgebietsgemeinschaft Elbe* emphasises sediments to such an extent, that it has a clear statement on chemical contamination and sediment's role therein. This is not the case in South Africa though. Based on this brief literature review, we hope that the exchange between the CSIR and DWS scientists we describe here will help elevate policy and scientific perceptions of sediments' role in transporting pollutants.

This paper consists of a number of parts. In the first section, we will briefly discuss theory and practice through action research. The second segment outlines the CSIR scientists' sediment transport research. We then discuss the uptake strategy for the sediment transport study and present the likely route of the uptake strategy. The paper ends with a conclusion on the lessons learned from the meeting between the two groups and the way forward regarding scientists communicating with decision makers.

[1] We would like to thank one of the anonymous reviewers for this argument.

2. Theory and practice: An action research perspective

A number of research tools are at scientists' disposal to reveal, explain, and understand problems. One such instrument is action research. Action research 'is a set of self-consciously collaborative and democratic strategies for generating knowledge and designing action in which trained experts in social and other forms of research and local stakeholders work together' (Levin & Greenwood, 2011, p. 29). This research methodology deals with problems created by disconnections inherent in the relationship between science and society. By applying action research, a closer bond between science and society is possible through knowledge generation and problem solving linkages. What is more, those practicing it consider action research a legitimate scientific practice (Levin & Greenwood, 2011). The methodology carries weight in the social scientific community as a robust knowledge generating methodology.

When considering relationships, or systems in which actors operate, roles come to mind (Rosenau, 1980). Roles refer to the actors' own definition of decision types, commitments, rules and actions and their function in the system (Le Prestre, 1997). Actors' different roles depend on a number of factors. The first is the issue that concerns them. Then there is the audience they try to influence and how they articulate the issue. The fourth factor is the nature and type of the actors and their cultural standing. The last group of factors is their political situation and status (Meissner, 2004). These factors can give the action researcher valuable clues when observing and analysing actors' interactions. Another interlinked and valuable element for analysing relations is theory.

Action research also links theory and practice (Levin & Greenwood, 2011). A theory is 'a set of principles on which the practice of an activity is based' or 'an idea used to account for a situation or justify a course of action' (*Oxford Advanced Learner's Dictionary*, 2005). Theory and practice are intertwined and mutually constitutive. Theories explain the connections between occurrences by presenting simplifications consisting of interrelated assumptions, definitions, ideas, and proposals (Grover & Glazier, 1986; Kerlinger, 1986; Koh, 2013). As such, multiple theories can explain events (Walt, 1998; Walt, 2005), issues, or situations. Scientists observe practices and create theories. Practitioners take the theories and practise them. There is also a close link between action research and practice. '[A]ction research is eminently practical' and 'the kind of theory that is most appropriate for explaining its processes is already within the practice, and emerges from the practice as the research develops' (Whitehead & McNiff, 2006, p. 2). In short, action research creates synergy between practitioners and scientists and theory and practice (Avison, Lau, Myers, & Nielsen, 1999) with reflective learning a productive outcome.

2.1. Scientists' 'Science' Defines their Reality

As mentioned, a link exists between science and practice (e.g. governance). The one feeds off the other; without proper and relevant knowledge, decision making falls to the way side and without the real world of decision making science becomes a hobby at most.

Science has the ability to produce relevant tools to assist decision makers in the day-to-day running of formal and informal organisations.

The definitions and concepts we use in everyday life determine how we see the world. Governance is a case in point, especially considering that this paper is about the interaction between scientists and government officials. Nevertheless, we do not define governance in terms of legal frameworks, hierarchies, and linear patterns of management only, although these are government characteristics. Governance exists in the context of dissimilarly empowered actors that negotiate and re-negotiate resource rights and their roles (Swatuk, 2002; Swatuk, 2005) in society or within a specific problem domain. Individuals, scientists included, can play an important role in decision-making (Meissner, 2005), from identifying and framing problems and their likely resolution to best practices in governance structures (Jacobs, 2010).

Scientists have the ability to influence decisions (Meissner, 2005). We know this as agential power; the ability to shape, influence and implement policy without the interference of social structures or other actors (Hobson, 2000). This creates a perception that in order to do so, the actor trying to shape or influence or to put into practice, must be powerful to overcome such structures and other actors. This is not the case all the time and everywhere. Here the notion of reflexive agential power or where an actor embeds itself into an assortment of societal structures, and not just a selected few (Hobson, 2000), is relevant.

Reflexive agential power as a strategy is also at the disposal of scientists wishing to influence or shape policy and the decisions that accompany them. Such a strategy would ideally start with a mind shift. This shift should be from the notion that it is only governments and their leaders that are influential, to another perception noting that any individual poses the ability to bring about change in society. To make such a change, researchers should not ask who governs and who benefits from governance efforts, but rather 'who acts and what are the consequences'. By asking the question differently, changes the perception of society from a top-down approach to one that is more horizontal (Hobson & Seabrooke, 2007) and inclusive (Meissner, 2017). This is not only necessary as a way to change perceptions, but also to assist scientists in realising that they can influence decisions at lower levels of the governmental hierarchy. Said differently, it is to emancipate researchers, but not to such an extent that they feel their products are necessarily what decision makers desire.

From this theoretical base, one can move forward meaningfully to consider a range of aspects concerning the science and policy interface that also need consideration. Before continuing a word of caution from Lepgold (1998, p. 59) on recommendations:

> 'One must remember, of course, that well specified arguments are no panacea in solving . . . policy problems. People [scientists included] differ in what they believe constitutes problems to be solved and can disagree about how to solve a problem, even if they define it similarly. Social science can clarify issues and choices for officials, but rarely can identify specific answers'.

The decision maker decides, and often the decisions are ordinary or critical; having dire consequences should they go awry. What Lepgold (1998) is saying is that it is not the responsibility of the scientist to provide all the answers all the time. This does not mean that researchers' have to sit back after they gave their opinions and answers; there exists a moral responsibility on the side of scientists to ensure, as far as possible, that decision support works for the better and not to the determent of society. This is especially the case in the water resource management domain; we are indeed dealing with a *life* supporting substance.

2.2. Science Not Speaking Truth to Power

Scientific knowledge 'is only an aid to the judgment of policy makers' and 'not a substitute for the judgment of policy makers' (Larson, 2003, p. 5). For instance, scientists feel compelled to go to DWS and expect decision makers to listen. Disappointment and frustration set in when researchers realise that they talk past policy makers. Scientists have to accept that they do not have all the answers all the time and need to accept that decision makers in many instances know what they are doing and even, in certain circumstances, know more (Sil & Katzenstein, 2010) than scientists do. Researchers also need to realise that decision makers will at times ask for a 'single best guess on an important problem', which can be an impediment to productive communication. '[T]he policy community should be more interested in analytical forecasting in which experts are asked to give a reasoned argument for what they expect to happen as well as suggest under what conditions something with a low probability might occur' (George, 1994, p. 172). Science does not always speak truth to power, because truth and power are not exclusive attributes of scientists and government officials, respectively.

What type of Knowledge? Based on the aforementioned how can researchers go about ascertaining the type of knowledge needed by decision makers? It is very simple, actually; researchers can ask the decision maker what type of knowledge he or she requires, and not assume that he or she is in need of the scientists' knowledge. The latter assumption is the engineering way of innovation; develop a product and test it through trial and error to determine its usefulness (Beckman & Barry, 2007). This is not wrong. It is, however, not the only way; there is an alternative and what follows are some practical pointers towards it.

Empathy Scientists need to be reflexive by becoming more emphatic (i.e. place yourself in the shoes of decision makers) and do not assume you have all the answers. 'Anybody can understand anything, as long as it is clearly explained – but more than that, if they are sufficiently interested.' The need for scientific knowledge is not the only reason for gaining new knowledge; motivation through interest can also be a strong incentive (Goldacre, 2009, p. 335). It is also up to the scientist to generate a motivation. Spending time with decision makers could be a way of discovering what drives them. Even so, scientists should be careful not to become embroiled in political disputes within organisations. Government employees and private sector practitioners can use scientists as a 'resource', either as a vent to get rid of frustrations generated by organisational politics or as a means to further arguments for or against policy perspectives and other officials. People create organisations and employ people with ambition and politics. This opens a new dynamic that can catch the researcher unaware making her or him think that what an employee is conveying is evidence when it is merely a data point.

An example would suffice. A colleague of ours, who had conducted research in a government department once, told the lead author about a chronic skills shortage in the department she studied. She interviewed an official from a government department and the official told her the department's skills shortage is quite problematic in that it is the root cause of the department not functioning properly. Our colleague put forward a list she had compiled during the interview process of the vacancies. This list was our colleagues 'proof' of the problem. Asking another colleague who is a career government official about the 'proof', she told one of the authors something else. Knowing the operational contexts of government departments, she said that vacancies do not necessarily indicate a skills shortage. She gave a number of alternative reasons for so many vacancies: budget cuts; restructuring; the official could be inflating the number of positions so the head of the department can elevate her directorate to a chief-directorate (government officials can employ this practice as a strategy for promotion); she could have lied or she could just be too lazy to fill the vacancies. Our informant indicated that in such a situation the best course of action is to visit the human resources department and obtain a copy of the departmental organogram that the executive had approved. This will indicate whether the vacancies are real or 'phantom positions', and if real, then one should ask why they have not been filled. This means that researchers should verify.

Open-disciplinarity Open-disciplinarity can shed further light on how to be more astute in verifying information. Open-disciplinarity happens when disciplines 'interact and seek to learn from each other, especially in analysis of a shared issue.' Gasper (2001) cites Berge and Powell (1997, p. 5) to explain open-disciplinarity as a situation where 'researchers identifying and confronting differences in perspectives and approaches; not . . . one to be [judged] "better" . . . but for each to learn from, and contribute to others; and hence also become more aware of the merits and limitations of their own [discipline]'. A link exists between open-disciplinarity and open-mindedness, where the underlying norm is learning from others and not judging each other's views as good or bad.

Based on this, a number of discussion questions can guide scientists during conversations with decision makers:

a. Does the policy maker know more about the issue than initially thought?
b. How does the decision-maker perceive the issue?
c. What are the opinions of outsiders regarding the official's knowledge of the problem?
d. What knowledge does the policy maker or actor require?
e. Are policy makers sufficiently motivated or interested in solving the problem?

f. Am I, as a scientist, imposing my views on the decision maker or actor, through recommendations or advice during conversations?
g. All in all, what can I, as a scientist, learn from the decision maker, even if it turns out to be irrelevant to my research endeavour?

It is also likely that the scientist had already conducted research and would like to disseminate the 'product' to stakeholders. This is not ideal, but at times unavoidable. In that case, the following questions could assist:

a. Is this research useful?
b. Can the decision maker use this research in her or his day-to-day decision-making?
c. What is not in the research that needs further research?

3. Soil erosion research

3.1. The Sediment Transport Study

The sediment transport study of the upper reaches of the Olifants River Basin was part of the Olifants River Research Project, sponsored by the Olifants River Forum. The project's overall aim was to investigate the ecosystem's health and its impact on water quality. The study consisted of around 30 scientists from the CSIR, the Universities of Stellenbosch and Pretoria as well as officials from the DWS and the Mpumalanga Tourism and Parks Agency. The need for the study emanated from the deteriorating quality of the river's water of which sediment transport is an important factor (Van Vuuren, 2010).

River sediments are imperative components of aquatic ecosystems since sediments provide habitats, feeding and spawning grounds for fauna and flora. Even though sediments are important and beneficial, they can also be detrimental especially with respect to reservoir siltation; excess sediments negatively influence water quality through turbidity. In addition, sediments can be the transportation media for pollutants such as metals or nutrients. When trapping such pollutants, sediments can act as sinks. Drivers of sediment overload are poor land use practices and activities such as agriculture, urban expansion, and mining. These may cause erosion, river siltation and unstable riverbanks and beds. According to Petersen, Jovanovic, and Genthe (2012), a knowledge gap exists in the understanding of transport mechanisms of sediments and associated pollutants. To fill this gap the sediment study addressed:

1. How are sediments reaching streams and how are they transported instream?
2. Where are they stored and how do river form, shape, and type influence storage?
3. Are there mitigation measures in place and what role do they play (Petersen et al., 2012)?

3.2. Engaging RQIS

In February 2013, scientists from the CSIR met with the DWS's RQIS officials. The lead author was the only social scientist present during the meeting and responsible for the meeting. The RQIS officials are not only public administrators, but water quality scientists too. The video conference meeting's purpose was to present the soil erosion study, its progress to date and initial findings to the RQIS officials. What follows is an account of the meeting.

The RQIS Directorate is responsible for monitoring water quality, and operates laboratories for testing water samples. The Directorate indicated that the toxicology screening of sediments is currently not at a level where scientists can obtain reliable measurements and this result in a low level of understanding of the role of sediments in transporting pollution.

The CSIR team then presented their research (summarised below).

- The Upper Olifants catchment and the influence of economic activities on its water quality were described.
- Research focused more on biological indicators than physical processes to determine water quality.
- High heavy metal, nutrient, and sediment levels are present.
- Scientists know about the sediment dynamics and pollutants link but are not able to quantify the processes and mechanisms influencing sediment, contaminant and nutrient transportation and storage because of lack of monitoring.
- Other unknowns are:
  - How knowledge could help with effective land use management and pollution mitigation.
  - How catchment activities influence river morphologies by transporting sediment-bound nutrients along rivers.
  - How catchment activities affect sediment-bound nutrient storage (Petersen & Jovanovic, 2013).
- The researchers could not record turbidity at regular frequencies with data loggers.
- The researchers compensated for this, carried out a geomorphic baseline study, and studied the role of river geomorphology in sediment deposition and transportation.
- They did electrical resistivity profiling to determine geological layering and groundwater characteristics.
- They described vegetation to indicate its influence on river channel form and pattern.
- The scientists chose two case study sites: one on the Koffiespruit and the other on the Wilge River (Figs. 1, 2 and 3). The two sites are located in agricultural landscapes, which will likely have the greatest impact as an anthropogenic activity. Both sites have operating DWS gauging weirs nearby that are essential for hydrological modelling. The sites are located some distance from each other and in different geomorphological zones.
- The study attempted to provide the baseline data to particular riverine ecosystems.
- A central argument by Petersen and Jovanovic (2013) is that a holistic understanding of river dynamics is essential before practitioners attempt to mitigate or restore river ecosystems and thereby contributing to river system conservation and management.

- Table 1 contains Petersen and Jovanovic's (2013) conclusions for both site surveys and Table 2 contains the study's limitations.

The RQIS's officials indicated that a low level of understanding indeed exists around sediments' role in pollution and appreciated the value of the CSIR's sediment study.

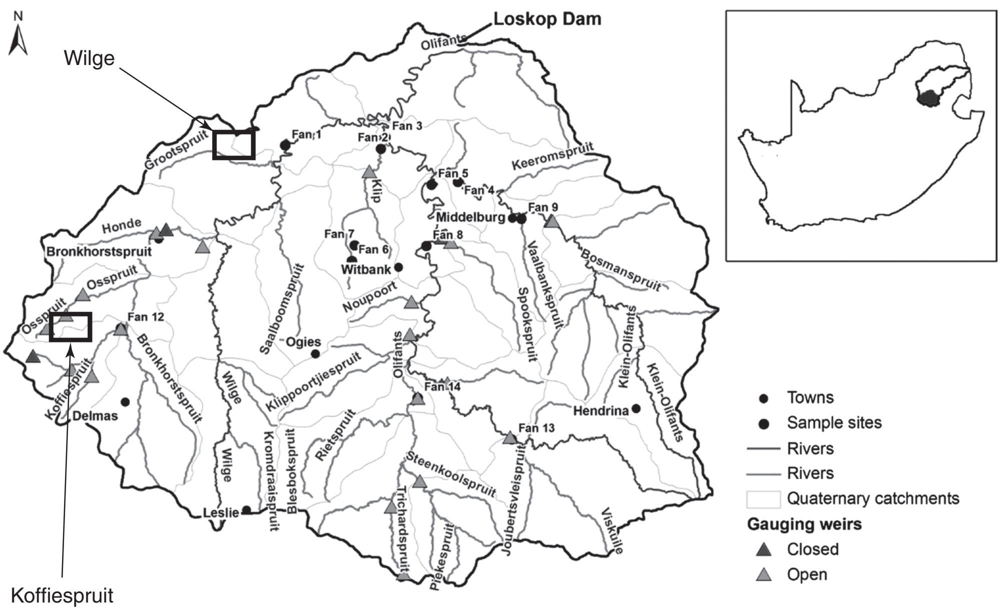

Figure 1. Site Location in the Upper Olifants River basin (Petersen & Jovanovic, 2013).

Figure 2. Site 1 on the Wilge River (Petersen & Jovanovic, 2013).

Figure 3. Site 12 on the Koffiespruit (Petersen & Jovanovic, 2013)

Table 1
Conclusions per Site

Site	Conclusion
Wilge River	Channel morphology changed very little during the study. Channel form remained stable influenced by dense indigenous vegetation. Substratum is armoured and very stable with bed changes likely during strong river flow. Cobble and boulder dominates the channel bed resulting in higher roughness during low river stages. Dense vegetation on the banks resulted in higher roughness during the high river stage. When farmers maintain the riparian zone, it continues to provide essential ecosystem services such as stabilising banks and sediment trapping. Geomorphic and hydrology processes strongly influence plant (species) distribution.
Koffiespruit	Grassland vegetation and an absent riparian zone, due to agricultural activities, influence variable channel shape changes. Channel form change is lateral and vertical with bank slumping and scouring. Bed changes in the form of incisions. Mobile sand dominates the channel bed in the pools and runs resulting in lower roughness than the Wilge site. Grass banks result in much lower resistance.

Table 2
The study's limitations

Limitation	Consequence
Budget constraints.	Adapting the study to focus mainly on fluvial geomorphology and its influencing factors. Limited samples: one vegetation survey and one resistivity survey at each site, and two river cross-sections surveys.
Lack of modelling.	No flow and sediment transport modelling.
Short time span.	Limited time of the study (2 years) during which no major flooding events occurred.
Lack of sediment monitoring in DWS.	No baseline to work from and no time series.

3.3. The Discussion

Following the CSIR's presentation, the group discussed the study and its conclusions and limitations. The RQIS officials inquired about the measuring weir on the Wilge near the sampling site. This was weir number B2H15. A RQIS official indicated that he was, at the time, doing an exploratory study near weir number B2H14—immediately downstream from the CSIR's study site. His study investigated flows at that cross-section to determine the stream's Péclet number.[2]

Another RQIS official asked about the sediments' grain size. The CSIR team used sediment sampling and tests to characterize particles from two millimetres to boulder size. The RQIS delegation indicated that they measured suspended particles smaller than one millimetre. The CSIR team explained that because they were not constantly on site, they do not know how many sediments are in suspension. The lack of continuous recording of turbidity and sampling for laboratory analysis was a central issue to the CSIR researchers. Had the equipment and resources been available, they would have had a better picture of the turbidity dynamics. The research team sampled river water only in July and September of 2011 and 2012 during low flows. The RQIS officials indicated that they have a year's data (on an hourly basis) for turbidity at the B2H14 weir site and made the data available to the CSIR team. The turbidity data could give a good measure of sediments in the river water and the CSIR team indicated that it would be interested in using the data.

In this regard, the CSIR team mentioned two issues continuously rearing their heads. The first is the lack of continuous monitoring, and by implication, records of sediment flow. The second are knowledge gaps of sediment-transported contaminants. These require more research. The RQIS officials concurred and indicated the existence of data in the United States and Europe on phosphate transportation. Even so, they were not sure who conducted structured investigations in South Africa and specifically on the nature of sediment and nutrient partitioning combined with mineralogy and nutrient transport characteristics.

[2] 'A Péclet number is a dimensionless number that can relate the effectiveness of mass transport by advection to the effectiveness of mass transport by either dispersion or diffusion' (Huysmans & Dassargues, 2005, p. 896).

The CSIR team asked about future river sediment monitoring plans. The RQIS officials would like to initiate such a programme. Currently DWS's toxicity programme would be responsible because current thinking is that pesticides and some heavy metals attach to sediments transporting the pollutants. The Department is not implementing sediment monitoring and is still investigating such a programme's design. For instance, scientists need to develop a laboratory monitoring methodology as part of the programme.

The CSIR also told the meeting of their follow-up study in the Wilderness area. Here, one of the focus studies is on lake sediments. The CSIR will place a similar probe that DWS uses at the B2H14 weir in the Wilderness area for monitoring river water quality. For the CSIR, it would be interesting to see how the hydrological system responds to rain events and sediment transport. The continuous monitoring of variables is of the utmost importance and the scarcity of data is a thorn in the practitioners' side. The CSIR team would like to conduct hourly monitoring since the nutrient concentrations change daily. On this matter, the RQIS officials said that phosphate does something peculiar; when the flow rate of a river increases the concentration of phosphate first increases as a "first flush" effect then it starts declining due to the dilution effect. This phosphate characteristic needs consideration during river flow and contaminant transport modelling. Both sides agreed that continuous sampling is the best practice. For the CSIR, variables like ammonia and nitrate are important to measure. One of the RQIS officials pointed out that one should be careful in using ammonia and nitrate-ion selective probes. According to him, they are not very stable, tend to drift quite frequently, and need weekly calibration.

In addition to the CSIR's Wilderness study, RQIS is rolling out a study in the same area at Swartvlei. They hope to do monthly, river salinity monitoring and water quality sampling for specifically nitrates and phosphates. They would also like to deploy probes in future to monitor depth changes, temperature fluctuations, and sediment.

The CSIR's sediment researchers also raised the issue of remediation; practical measures that will reduce sediment transport. Here the riparian buffer zone is of particular importance since it can reduce sediment transport before sediments reach the main river channel and are transported downstream. Vegetation in wetlands and indigenous trees can play an important role, in terms of not only buffering contaminants, but also regarding biodiversity. In the Western Cape (South Africa), farmers restore the riparian buffer zone using endemic fynbos and clear alien vegetation. Clearing alien vegetation also leaves the banks vulnerable to erosion as long as no vegetation is present. Farmers should also consider replanting riverbanks when clearing. Erosion is also an issue and here remediation involves a change in farming practices or allocation of land as the riparian buffer zone. The CSIR wanted to know what the attitude of farmers are regarding the buffer zone.

The officials indicated that it would not be a problem with commercial farmers, since they cultivate large tracks of land and can afford to give up some land to the buffer zone. Many of them are already doing it, especially sugarcane farmers in parts of KwaZulu-Natal near Twinstreams (Mtunzini) where they had increased the buffer zone and that prevented further sedimentation of the Siyaya catchment. The implementation started with one farmer and then others followed in cutting back cultivation from riverbanks. Forestry companies have also started doing this. This has a positive influence on not only stream hydrology but also river water turbidity. A buffer zone could also trap sediments carrying phosphates, nitrates and other contaminants. Subsistence and emerging farmers are directly dependent on the buffer for crop production. Since it is usually close to the river, the track of land can be easily irrigated using small petrol pumps or even hand-driven pumps.

The establishment and control of riparian buffer zones fall in the DWS's legislative domain as well as the policy sphere of the Department of Environmental Affairs (DEA) and the Department of Agriculture, Forestry and Fisheries (DAFF). This could make implementation problematic. Also, urban waste water treatment works are huge contributors to phosphate loads in rivers and the law can play a role in mitigating this. Yet, a wetland constructed directly downstream could also have a positive influence.

4. Uptake strategy

From the discussion between the two groups, we can draw some conclusions. It is clear that there was a mutual exchange of information and knowledge between the two groups of scientists. This was an indication that there were gaps in knowledge on both sides. For RQIS and the CSIR, continuous data and records of sediments are priorities and for RQIS the development of a sediment monitoring methodology is of importance. Here collaboration between the entities could fill the respective knowledge gaps. During the discussion, it became clear that it is not only a matter of science produced by the CSIR informing RQIS concerns around sediment-transported pollutants, but also a matter of science from RQIS informing the research programmes of the CSIR researchers.

This is an important observation for it discards the notion that science and technology informs policy and decision making within government and that government enables and facilitates scientific processes through policy, resource allocations and strategic direction (like Turton, Hattingh, Claassen, Roux, & Ashton, 2007 asserts). This might be the case at the macro or national level, but the discussion between the respective institutions' scientists indicated that it takes a different form at the individual level. The two teams influenced each other, showing that science does not always influence policy. A particular example of this is RQIS alerting the CSIR researchers about the constant calibration of the instruments and where the CSIR raised the issue of the riparian buffer zone. There was, therefore, mutual influence and science enabling. A clear division of labour fell by the way side. The reason for this could be the roles of the individuals from the respective institutions: all are scientists and understand the scientific process and its drawbacks and values to the policy process (see Table 3). The scientists present played different roles before and after the discussion and had different interests in the study. Table 3 indicates these roles and interests. We developed this interest and role list based on the various factors influencing actor roles. Based on this, it would be in the best interest of both institutions to keep an open channel of communication regarding not only data and knowledge exchange, but also to update each other on progress of their respective studies. From a strategic perspective, this could avoid duplication and subsequent wastage of valuable resources.

Table 3
The Attendees' Interests and Roles

Attendees	Interests	Roles	Factor Influencing the Adopted Role
CSIR			
Natural scientists	Conducted the study and would therefore see it influencing policy. The study to make a positive difference to deteriorating environments through scientific knowledge. The study to make a positive difference to the human condition through better farming practices and less polluted rivers. Contribute to the scientific knowledge of sediments in general. To see human behavioural change after making a scientific case for sediments transporting pollutants.	Policy influencer through science. Objective watchdog over the environment. Empirical philanthropist advancing the human condition. Scientific (empirical) knowledge generator. Behavioural changers through education.	The scientists perceived the audience as policy makers. The scientists are concerned over the issue of sediments transporting pollution and combating soil erosion. The scientists' issue is that they want farmers to protect the riparian buffer zone through better farming practices. The scientists are by their very nature and type actors in the scientific community. The scientists are also by their nature and type educators in universities.
Social scientist	Convened the meeting and would therefore point out that science can interface with policies at any level. Show that the social sciences can play a meaningful role in organisations steeped in the empirical research tradition.	Facilitator. Observer. Advocate for advancing social scientific knowledge.	The scientist is by his very nature and type of actor a political scientist with an understanding of the policy environment. Observes policymakers (the audience).
RQIS			
Natural scientists	Attended the meeting to gain more knowledge on the subject. Gave information to indicate knowledge on the subject. Gave information for scientists to improve on future sediment studies.	Inquisitive observer. Empirical scientist Objective reviewer. Co-developer of further knowledge. Public administrators or government officials.	The issue for these scientists are sediments influencing water quality. Their vocation as public officials determines their political situation. They are, by their very nature and type of actor, also natural scientists. Because they are also natural scientists (nature and type of actor), they played the reviewer role. They are water quality specialists that influence their knowledge co-development role. Their vocation as public officials determines their political situation as public administrators or government officials.

When planning to engage decision makers, scientists should know that decision makers could play different roles during the encounter. Not all government officials play a public administration role that listen to scientists and then decide whether to uptake the knowledge into policies. This study indicates that government officials and scientists play varying roles during the encounter with one another. This means that the communication did not flow from the scientists to the RQIS officials, or vice versa. The meeting took the form of a dialogue, and at times, a review of the sediment study by the RQIS officials. The reason for this would be the knowledge gaps in sediment-bound pollutant transportation that necessitates both groups to inform each other about knowledge to fill the gaps. The exchange of information between the two groups also indicated that scientists need to consider the type of actor, and its roles and interests, they are likely to encounter during science-policy communication. Such a determination can be of immense strategic value in the scientists communicating successfully or not with decision makers. One of the most important factors that facilitated the exchange is that both sides understood the sediment-bound pollutant theory. What is more, the uptake strategy was possible because of the authors' observations during the meeting. The social scientist was able to participate in the meeting and through observing the scientists' practices, interests, and roles, able to develop the strategy. In the process, we were all able to learn from one another through reflexive agential power. Not only did the lead author embed himself into the knowledge of the natural scientists, the natural scientists were also embedding themselves into each other's knowledge domains and structures. After reflecting on the different roles, we now know that the RQIS structure is not only that of a government entity, but also a science structure with multiple roles and interests. Because of diverse structures, roles and interests, panacea type arguments would have been unproductive. During the meeting, the CSIR researchers did not promote panaceas but rather used the exchange as an opportunity for a deeper understanding. The CSIR asked numerous questions, indicating that they did not possess all the answers on the issue. The absence of the turbidity monitoring was probably a determining factor. Yet, even with the data, the CSIR scientists would still not have had all the answers because of the general knowledge gaps of both groups.

Both organisations face similar issues regarding the lack of knowledge on continuous monitoring data and knowledge regarding the transportation of pollutants through sediments. This mutual interest should be another driving force behind collaboration between RQIS and the CSIR. The study areas are in close proximity and this reinforces the rationale for closer cooperation. The fact that DWS was in the process of starting a sediment-monitoring programme could have been a valuable opportunity for the CSIR to give inputs into the design phase and throughout the project as both parties could learn valuable lessons. These knowledge gaps were sufficient for an emphatic reflexivity because both sides knew the ramifications of knowledge gaps in conducting science and developing water quality programmes.

Regarding knowledge gaps and gaining a better understanding, we would recommend that scientists become more open to other sciences and disciplines to advise one another on knowledge generation and uptake. This paper attests to the productive contribution that different sciences (natural and social) and scientific disciplines (sedimentology, toxicology, and political science) can play in filling knowledge gaps and deepening understanding. On this, we would like to recommend that in future scientists should make use of an open-disciplinary strategy. This starts by having an open mind about other sciences and the contribution that different disciplines can make to problems facing humans and the environment.

With respect to remediation and the creation or enlargement of the riparian buffer zone, we recommend that the CSIR target the farming community. There is already a norm driving the enlargement of the buffer zone in certain agricultural sectors, like sugar cane growers. The CSIR could use the knowledge already gained on this issue to reinforce such norms. Scientific proof is a well-practiced way of exerting influence over policy processes, not only at government but also at individual level (Rosenau, 1990). Scientific proof carries the potential to reinforce the norm should the proof indicate the positive benefits from enlarging the buffer zone. Here a popular article in agricultural magazines could be a medium of communicating the positive aspects of buffer zone enlargement, establishment, or remediation. Such an article could prove influential among the farming community.

5. Conclusion

This paper reports on a collaborative endeavour, organised by the lead author, to generate mutual knowledge that can help in designing meaningful action to fill knowledge gaps on sediment-bound pollutant transportation. The meeting was a once-off event that established an information exchange between two groups of scientists. During the meeting, the trained experts collaborated as scientists by informing each other of knowledge gaps and other scientific pitfalls. These problems are manifestations of the disconnections between science and government officials and specifically what the one group knows is unknown to the other. The CSIR's sediment study has the potential to strengthen cooperation between the CSIR and RQIS around continuous monitoring, record production, and information exchange. Since sediments are an enigmatic research field, the soil erosion study is an important step in the right direction to give more substance to the research field and inform its future progress. This could become a valuable knowledge source for RQIS in their efforts to develop a sediment-monitoring programme. Said differently, the soil erosion study could become the foundation of future research designs and innovations for RQIS. The study also has the potential to make an impact at the individual farmer level, since the findings on riparian buffer zone enlargement corroborates the practices of sugar cane growers in KwaZulu-Natal. For all this to happen, the scientists need to keep an open line of communication with RQIS and target the farming community through a science-based communication.

How scientists perceive the policy environment will have a bearing on the design of science uptake strategies. If a scientist sees the policy environment where government is the most important actor, which can have a deliberate bearing at all levels of society, the uptake strategy will most likely focus on governmental actors. Researchers should not only aim their strategy at higher echelon government officials, but also at those officials that work directly with the issue under investigation. To be sure, focussing only on top officials, thinking that they will have more influence than lower-ranking government employees, is a lopsided perspective of the policy process and the actors involved. This can lead to the wastage of time when scientists communicate with only one actor. Society is complex with interdependencies slicing through hierarchies and connecting the seemingly unconnected. Since theories are representations of reality, theory is central to scientists' pragmatic approaches to policy uptake.

From the discussion with the DWS delegation, it became clear that scientists are already directly part of the policy process. Mutual learning between the two parties was the most likely outcome in both policy domains. Scientists should not always try to produce legislation when engaging decision makers. The challenge for scientists is to broaden the scope of actors in their uptake strategies to include not only government but also private individuals. Here closer contact with farmers' associations could play a decisive role. Workshops can build closer cooperation, face-to-face meetings, and even video conferencing, such as the one with the RQIS delegation, can build closer cooperation.

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