TOWARDS A COMPREHENSIVE FRAMEWORK TO GOVERN THE MAIN SUSTAINABILITY ISSUES OF INLAND INDUSTRIAL COMPLEXES

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Economic expansions generally mean that more natural resources will be used. Apart from increasing pressure on the environment, an array of social and institutional implications is also associated with the expansions. This is especially true for inland industrial complexes in South Africa. The social and economic benefits warrant the government's support of such industrial complexes, but the negative consequences, for present and future generations, need to be considered in a comprehensive manner to govern the complexes. The study subsequently set out to determine what constitutes the sustainability of an inland industrial complex with respect to governance issues. That is, what sustainability includes, for whom, and why sustainability is pursued, so that the goals for various stakeholders can be defined. Rather than an exact, quantitative model to measure the sustainability, a qualitative framework was developed to determine appropriate strategies, and to know how those strategies will influence the system. The framework is a combination of qualitative system dynamics and the general protocol for translating visions into goals for multi-party systems; the non threatening characteristic of the system dynamics approach and the ability to model a complex system in an understanding way is combined with the specificity of the nationally accepted general protocol, which is used for obtaining consensus in a multi-party system. Information about the sustainability of inland industrial complexes was obtained from an existing complex that has been monitored frequently. The most important criteria, or performance indicators, are defined, which can be used to evaluate the extent to which sustainable development is achieved. For this set of criteria to be complete, the nature of the problem was analysed and the different (stakeholder) perceptions of sustainable development were taken into account. This provided insight into the main problems of inland industrial complexes in a broader perspective and contributed to setting the boundaries right and finding proper directions for solutions. From a water resources perspective these solutions need to address the following main (system) problems: if water is polluted more, then industry uses more water; if water is scarce, the price does not go up under free market conditions; and there is a time delay to adapt the price of water to the scarcity. The paper concludes how governance interventions may address these problems of inland industrial complexes.

INTRODUCTION

The government of South Africa has committed itself to achieving more sustainable development goals by signing the United Nations Millennium Declaration. However, despite this progress, there still lie several various challenges to be overcome in order to reach its sustainable development objectives (1). A growing population that is both quickly developing and increasingly exploiting export opportunities will increase the demand for energy production. This offers prospects for the energy companies and other industries in South Africa to expand.

Undoubtedly, the current energy expansion plans will put pressure on the natural environment, and, in turn, will generate an array of social and institutional implications. This is especially true for inland industrial complexes in South Africa. It has been reported that a serious threat of water shortage and further deteriorations of water quality are expected in the catchments currently used by the industrial complex in Secunda (2). At the moment there is an indication that the ecosystems are already under severe stress (3). For example, incidents of deaths of crocodiles and fish have been reported. In addition, outbreaks of infectious illness and deaths have occurred in the area and these are attributed to untreated ground and surface water in South West Free State (4) and Mpumalanga (5). The indicator of negative impacts on the ecosystems caused by pollutants in waste streams is signified by the presence of blue green algae in the riverline, and this problem has reached unacceptable levels (3). Subsequently, sulphides, heavy metal release from sediment and chemical oxygen demands have increased due to algal blooms (6). On the other hand, it is doubtful if the yield of an expanding inland industry in South Africa will contribute to economic sustainability in terms of contributing to the eradication of poverty for the surrounding communities, since the benefits are not directly shared with everybody in the affected area.

Nevertheless, it may be that the social and economic benefits might warrant the government support of such industrial complexes. In such circumstances it will become very important that the negative consequence, for present and future generations, should be taken into account in a comprehensive manner to ensure that the complexes are properly governed from the planning phases throughout their operational life.

<u>Institutional measures to manage and plan inland industrial complexes</u>

Inland industrial complexes and surrounding support structures are known to be significant consumers of water in a country with limited resources (3). Furthermore, both point and diffuse pollution can arise from a wide range of activities that are undertaken at these complexes. In order to ensure sustainable growth it is thus important not only to nurture the economic wealth generating aspects of these complexes, but also to ensure that they do so in an environmentally sustainable way.

It is a well known fact that the environmental risks arise largely from the very nature of industrial activities. Thus the management of these risks can either reduce or exacerbate the risks depending on the way in which this management is carried out. More than often, waste residues are stored on site for purposes of use as a resource in future. This helps to minimise effluent discharge on site or as a regulatory “requirement” in order to operate as a zero-effluent facility. However, this does not mean that the challenges of pollution are completely eliminated. This is just a mode of merely transferring the problem from one medium to another into the future. It must be noted that despite the gains of industry in reducing polluting activities through internal recycling and re-use and the implementation of cleaner production principles, and, likewise, the efforts by regulating authorities to balance the need for economic development with the need for environmental protection on a case by case basis, there still remains questions as to what degree have these efforts helped to the success of attaining environmental sustainability of these industrial complexes. Therefore issues such as cumulative effects should be considered because they are bound to cause a long term environmental liability of these complexes. Hence, either way, a better knowledge base should help to identify opportunities to attain a more sustainable future for these complexes.

This paper represents one part of a larger WRC-funded research effort to assess the regulatory and other stumbling blocks that impede the implementation of synergistic reuse options and integrated technical solutions in complexes on the basis of industrial ecology (7). It is envisaged that the outcomes will assist government official to make decisions based on evidence and that currently mistakes should not be repeated in the planning for future industrial complexes in addition to taking corrective measures for the challenges being experienced in current facilities, such as the management of run-offs from waste dumps.

CONSULTATIVE APPROACH TO INLAND INDUSTRIAL COMPLEXES

The investigation focused on the sustainability of the water systems that are associated with the Secunda inland industrial complex (2) and the main purpose of the consultative approach was to determine: "*what constitutes the sustainability of an inland industrial complex with respect to governance issues*". In other words: "*to investigate what sustainability includes, and for whom, and why sustainability is pursued, so that the goals for various stakeholders can be defined*" (8).

To obtain a comprehensive framework to govern the main sustainability issues of inland industrial complexes requires that the set of criteria or indicators are thorough and complete. Such a set had been developed for the Secunda complex (see Figure 1). In this way, one ensures that the problem is analysed and the different perceptions of sustainable development are taken into account. This in turn, provides insight into the problem in a broader perspective, and hence contributes to setting the boundaries correctly. This ensure that not only are the technical, economical, social and environmental issues captured, but also the institutional issues, thus leading to good governance for the sustainability of an inland industrial complex and the water systems on which it depends.

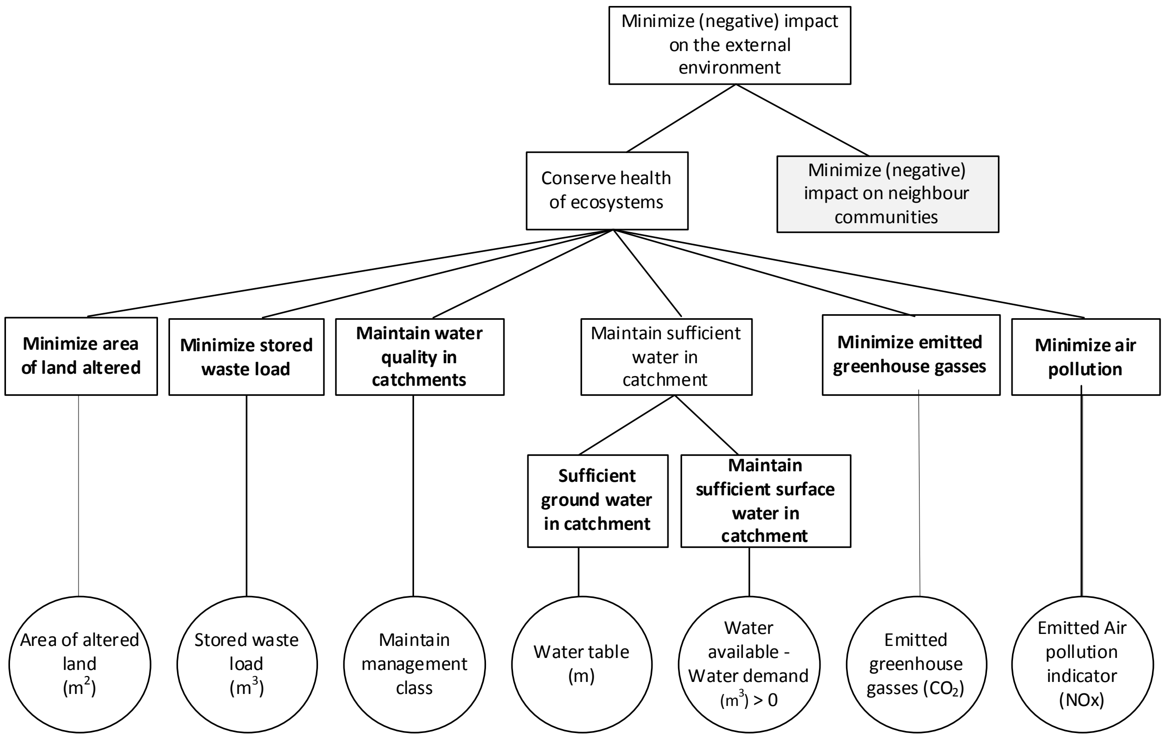

Figure 1. Hierarchical tree of external environmental impacts of industrial complexes (8)

Systems approach to sustainability

In a complex situation, problems are often ill-structured. This is because the system in which the problem occurs is multi-disciplinary. There are several issues to be addressed such as technological, economical environmental, social and institutional, including multiple stakeholders with different perceptions and interests that play a role.

A "*system*" is defined as part of the reality that is being investigated in response to an assumption of a problem (9). The focus of this study was on the effect of an inland industrial complex on the external environment, specifically water, and possibilities how governance issues would affect the sustainability of the complex (see Figure 1). The system boundary was set around all the variables that influence decision making on sustainability of inland industrial complexes. To evaluate the extent to which sustainable development has been achieved requires that criteria or performance indicators are set. These are the variables/tools that can be used to measure the extent to which the goal has been achieved and obtained and are themselves influenced by the system, in turn (9). The endogenous variables are the variables within the system that influence the criteria. The success of the system depends on the existing relevant instruments in the country.

An instrument is a tool that the problem owner can use to change the system, such as policies, rules and regulation; thus the system, and therefore the endogenous variables, can be changed by use of an instrument. The system itself is also influenced by variables that cannot be influenced by the problem owner. These are called exogenous variables. The way a system works is shown schematically in Figure 2.

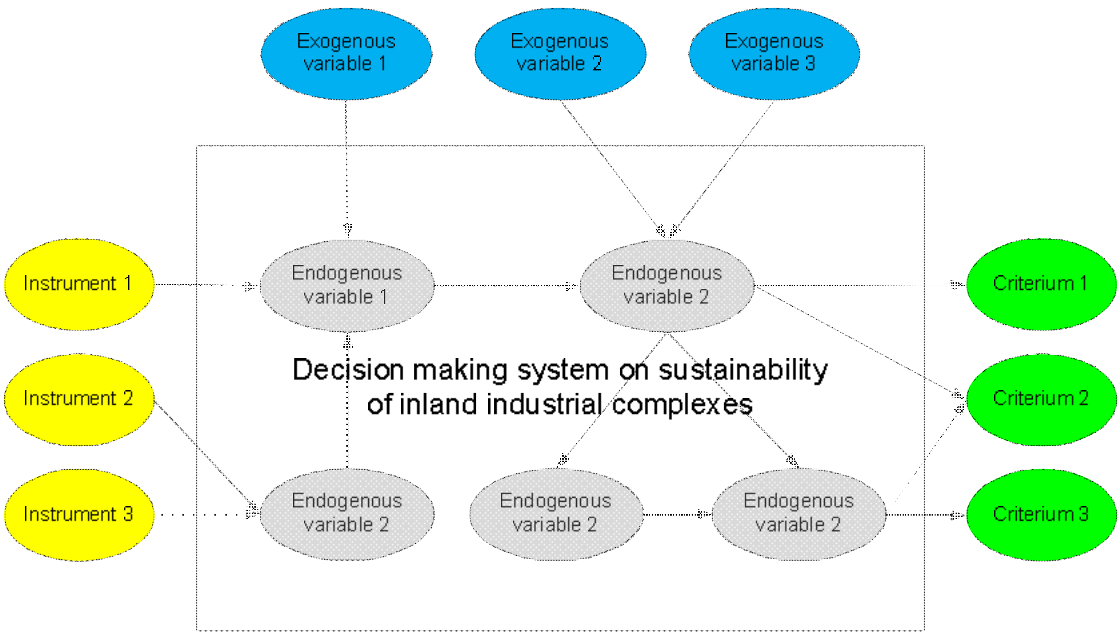

Figure 2. Schematic representation of the workings of a system

Appropriateness of a system dynamics approach

One of the main questions that had to be answered was: "*Can qualitative system dynamics analysis of a complex system contribute to speeding up the process of consultation with stakeholders and gain consensus on the purpose of multi-party systems, in order to model and govern sustainability of inland industrial complexes?*" To achieve this requires a few crucial steps and parts had to be accomplished (8).

The first step was to validate a hierarchical tree of sustainability criteria with stakeholders (see Figure 1). The main purpose of the validation was to test whether the stakeholders concur with the thoroughness and completeness of the set of criteria and that the set provides good support when governing sustainability.

To do this properly required the second step which was to know more about the stakeholders in the industrial complex system. The keys issues were to know their individual roles and interests and what their formal powers are and how the stakeholders are interdependent. Therefore an extensive stakeholder analysis was performed.

The sustainability of an inland industrial complex cannot be controlled by the design option only, such as the size, type and location. The criteria for sustainability are influenced by many subsystems and how variables of those subsystems interact with each other. This is schematically described in Figure 3. The other systems include water provision, socio-economic issues, air pollution and land use, which in turn are influenced by decisions of several stakeholders. Therefore the third step was to investigate the structural behaviour of the system. The structure can provide insight as to why the system is in or out of control.

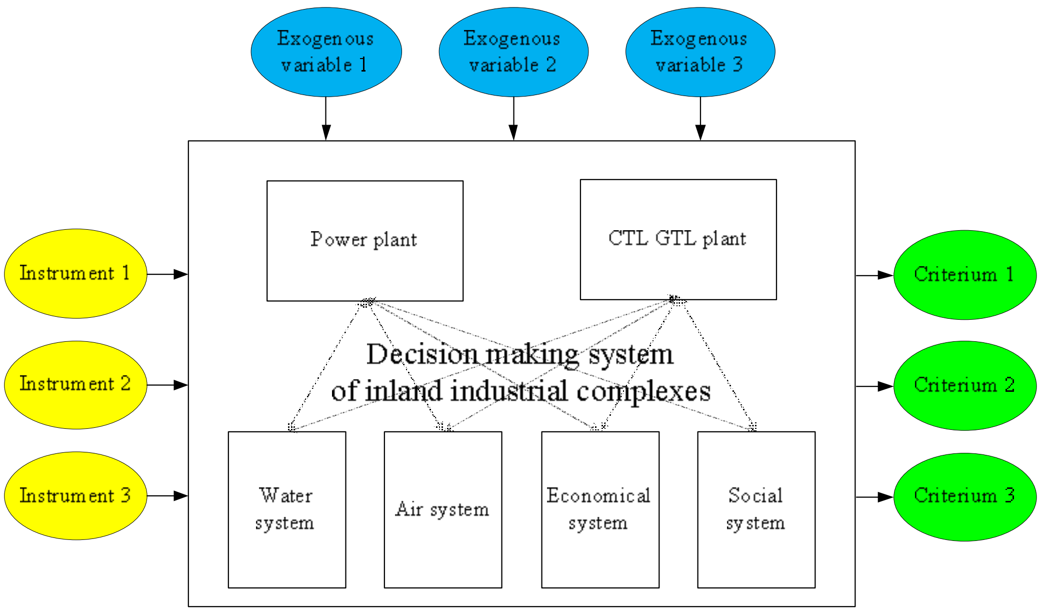

Figure 3. System with subsystems

The defined criteria together with the insight of where action or attention is required, and by whom, can be used to ascertain the effects of policies, and other behaviours, such as institutional arrangements, that influence the system to evaluate the most appropriate sustainable development strategies for the government, and other involved parties. The aim is to improve sustainability and to avoid possibilities that may impede on the sustainable development of inland industrial complexes.

Perceived goals of involved parties

A "*desired state*" approach was incorporated, which is used for obtaining consensus, as described in the DEAT General Protocol for translating visions into goals for multi-party systems (10). This approach includes:

- Identifying the parties in the multi-party system, their values and needs. This includes: identifying the stakeholders and the interested and affected parties;;

negotiating their level of participation; and identifying and recording the visions and objectives of each party for the issue at hand.

- Gain consensus on the multi-party systems' purpose and operating procedures. This is achieved by: gaining consensus on the purpose of the multi-party system; integrating the visions and objectives of all parties by documenting, evaluating and consolidating the strengths of the system and recording all the determinants of, and constraints and threats to the strengths.

NETWORK AND STAKEHOLDER ANALYSIS FOR THE SECUNDA COMPLEX

Major users network

Water shortage is one of the major expected issues to consider when planning the expansion of inland industrial complexes. Therefore for this investigation the water users are described together with the determination of their relative requirements and their commitment to the improving the sustainability of water systems.

The expected deficit in water supply has been investigated by DWAF in each Water Management Area (3). The Secunda area is mostly located in the Upper Vaal Water Management Area. The major users of water are mining and bulk industry, power generation, followed by agriculture and communal users, urban and rural (see Tables 1 and 2).

Table 1. Year 2000 water requirements catchments affected by Secunda area (3)

		Irrigation	Urban	Rural	Mining and bulk industrial	Power generation	Total requirements
Wilge	requirement (Mm^3/a)	18	27	15	0	0	60
	% of total	30%	45%	25%	0%	0%	100%
Upstream of Vaal dam	requirement (Mm^3/a)	29	32	17	99	39	216
	% of total	**13%**	**15%**	**8%**	**46%**	**18%**	100%
Downstream of Vaal dam	requirement (Mm^3/a)	67	576	11	74	41	769
	% of total	9%	75%	1%	10%	5%	100%

Table 2. Year 2025 base scenario water requirements catchments affected by Secunda (3)

		Irrigation	Urban	Rural	Mining and bulk industrial	Power generation	Total requirements
Wilge	requirement (Mm^3/a)	18	25	13	0	0	56
	% of total	32%	45%	23%	0%	0%	100%
Upstream of Vaal dam	requirement (Mm^3/a)	29	36	17	99	75	256
	% of total	**11%**	**14%**	**7%**	**39%**	**29%**	100%
Downstream of Vaal dam	requirement (Mm^3/a)	67	763	10	74	43	957
	% of total	7%	80%	1%	8%	4%	100%

Tables 1 and 2 only provide information about water use; it does not provide information about the levels of pollution. For example, the acceptable levels of ammonia have been exceeded as well as the acceptable level of total dissolved salts (11). However, the contribution of each water user (or polluter) is unclear. It is difficult to assess due to limited monitoring in the footprint. For example, there was no aquatic or habitat data available from elsewhere in the footprint to assess the contribution from Sasol mining to the ecological integrity (11).

Involved stakeholders

A list of stakeholders that should be involved has been proposed (2). This list has been discussed with stakeholders and suggestions were made as to some additional stakeholders. The critical stakeholders were identified as follows:

- Governmental organisations: Department of Water and Environmental Affairs (DWEA); Water Research Commission (WRC); Upper Vaal Catchment Management Agency (CMA); Water User Association; Provincial government of Mpumalanga; District municipalities (Nkangala, Gert Sibande); Local municipalities (Govan Mbeki, eMalahleni); Lesotho Highlands Water Commission; Eskom; National Energy Regulator of South Africa (NERSA); Mpumalanga Department of Agriculture & Land Administration (MDALA); Water boards; and Parks board.
- Commercial organisations: Sasol Synfuels Secunda; Sasol Coal Mpumalanga; Agri-SA; Sappi; AECI; Evander Gold Mines Mpumalanga; Eskom; New Denmark Coal Mines.
- Other organisations: Mvula (water and sanitation NGO South Africa); Olifants River Forum; New Denmark Coal Mines

SYSTEMS DYNAMICS ANALYSIS

As already described above system dynamics is a method used to qualitatively describe a complex system which facilitates quantitative simulation modelling and analysis for the design of system structure and control (12). Since system dynamics is a time consuming approach, only the major issues in the system and feedback loops were validated with the stakeholders and used to gain consensus and create interaction. There are several ways to perform a system dynamics analysis; the following six major steps have been suggested (13):

- Problem identification;
- Model conceptualization;
- Model formulation;
- Model analysis and validation;
- Policy analysis and design; and
- Implementation

In this investigation, the first two steps were executed. It is only after this that the usefulness of performing the next steps will be considered.

The goal of the conceptualisation of the model is that it: "*focuses attention and draws out a shared view on the key driving forces that determine the future of the industry/business and the companies relative performance*" (14). The conceptualisation also improves the understanding of relations between substructures and behaviours related to the problem. Since "*a broad model boundary that includes important feedback effects is more important than a great amount of detail in the specification of individual components*" (15), boundaries were set broad initially (8). This was explained clearly to the stakeholders, since, as is mentioned before, the long-time horizon and wide-boundary approach of system dynamics can be problematic for the modeller-client interaction (16).

Validation of internal structures

Usually validation is performed after the model is formulated. However, validation does exist in every stage of the methodological approach (13); validity of a system dynamics model primarily means validity of its internal structure. A white-box model, being a 'theory' about the real system, must not only reproduce or predict its behaviour, but also explain how the behaviour is generated. Accuracy of the model behaviour's reproduction of real behaviour is important too, but this can only be meaningful if there is already sufficient confidence in the structure of the model. Testing the validity of the qualitative system dynamics model can be done by an empirical direct structure-confirmation test (13). There is a limit to the confidence in the model: "*one can achieve only a degree of confidence in a model that is a compromise between adequacy and the time and cost for further improvement*" (17).

<u>Feedback loops</u>

The causal loop diagram has been made for the water system. This is the main issue, from the objectives of the investigation, and most other systems relate to the water system. In addition, to find out whether a qualitative system dynamics analysis contributes to speeding up the consultation process with stakeholders, and gain consensus on the purpose of multi-party systems, not every aspect needs to be modelled. The major part should be sufficient. However, the other issues that relate to the criteria in the comprehensive hierarchical tree (see Figure 1) were discussed with the stakeholders as well, since this is required to govern the main sustainability issues of inland industrial complexes.

<u>Salinisation</u>

A major issue in the complex is the salts from processes that create large stored waste loads. Process waste covers around five squared kilometres of ash and slime dams and product waste has the order of magnitude of thousands of millions of tonnes. Chemical reactions can take place when the insoluble salts are stored, after which they can precipitate into the ground and surface water. Turbulence can also cause erosion. The more water quality stringent measures from the government for the allowed level of pollution in water, the more process and product waste will remain after treatment of the water. Other complications arise because of the price for desalination and the low amount of measurements of the stored load. Lastly, there is not enough policing, which makes laws and regulation fail to control this issue. Despite these issues, no major feedback loop was detected for salinisation in the model (see Figure 4), although this aspect has bearing on water quality in general.

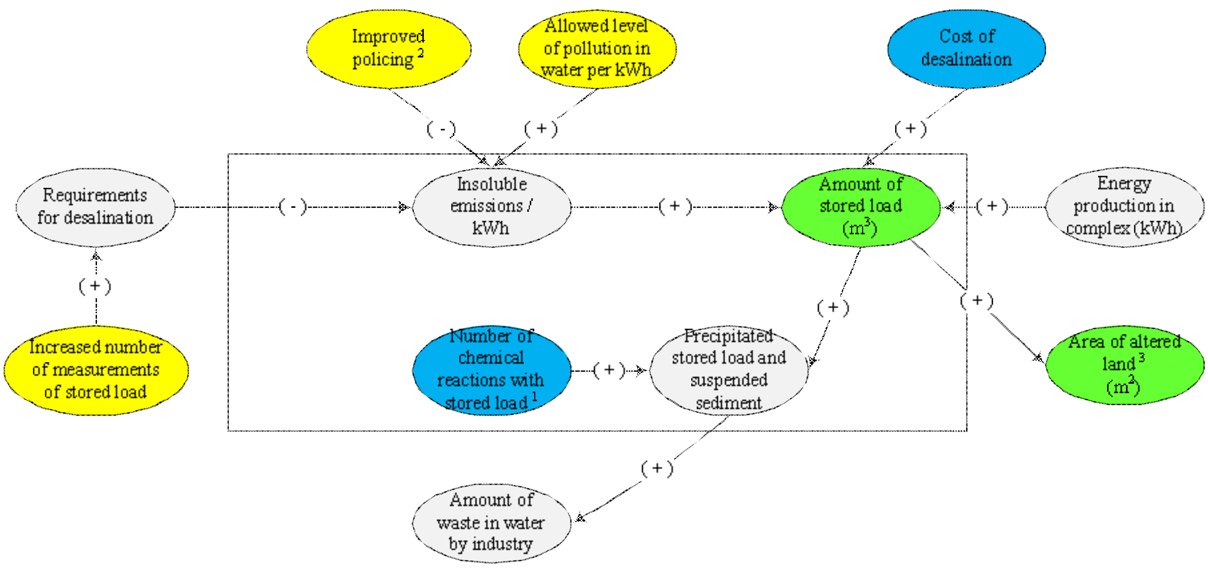

Figure 4. System dynamics analysis of the salinisation problem in the Secunda complex

Water quality

If implemented properly, the water quality can be controlled by the allowed level of pollution in water, since it increases the need for water treatment. However, it is expected that, if the water the industries receive is of bad quality, the industry needs more water for their processes, since the equipment can only handle a certain amount of pollution because of, for example, the technical limitations of reverse osmosis. Therefore the water needs to be mixed with fresh water. It is common knowledge that when more water is taken from the catchment by one system, less water is available for other users in the same catchment and with the same amount of waste the level of pollution in the water will increase more. This provides a simplified positive feedback loop, which is out of control, namely, if water is polluted more, then industry uses more water (see Figure 5).

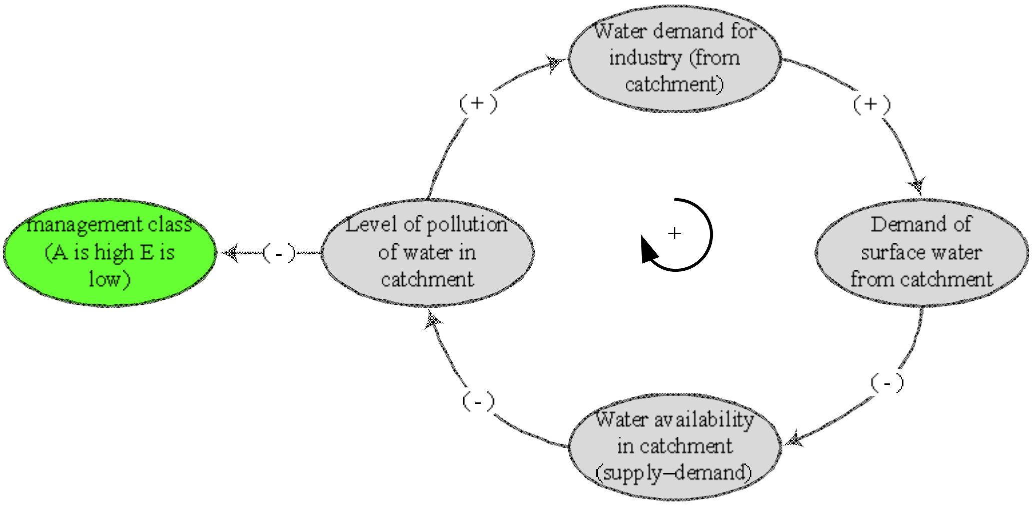

Figure 5. Water quality positive feedback loop

Water quantity

In addition to water quality, water quantity plays an important role. Likewise water quantity could be controlled by a feedback loop. It is likely that the water demand from the industry will increase, especially because of the increased demand for electricity as more water will be used in the process of electricity generation. This will result in less water available in the catchment. Under normal free market conditions the scarcity of a resource should increase the price. However the price is set by the government. This implies that the feedback loop is positive, and that the system gets out of control, namely, if water is scarce, the price does not go up under free market conditions, and there is a time delay to adapt the price of water to the scarcity (see Figure 6).

DISCUSSION

Water quality – Stakeholder perceptions of the identified feedback loop

At present DWAF 'hopes' water quality will not deteriorate, and that it will be under control: "*Any infrastructure development has an impact on the environment. For all these developments EIA's must be done. The necessary permit authorizations must be obtained from the environmental authorities. That is the rigorous process that has to be undertaken That Record of Decision (RoD) will reveal what is allowed and what is not and how to mitigate the impacts, which there will always be*". DWAF is busy investigating the implementation of a waste discharge system whereby the industries will pay a penalty if they discharge water that is of a poorer quality than the set standards or guidelines. It is hoped by DWAF that this will discourage industries discharging water that is of poor quality.

Sasol is of the opinion that the water quality will deteriorate significantly because the salinity is going to increase. There is going to be an organic problem, because of deteriorated water from the Grootdraaidam and Vaal River, since water there is not treated to requirements; this is a new concern: "*Historically, the focus is on the saline deterioration of the water, but now there is organic and nitrate pollution of the water, because the sewage doesn't work. From an industry point of view, the water treatment processes are not geared with dealing organics from the raw water, and nitrates and phosphate*".

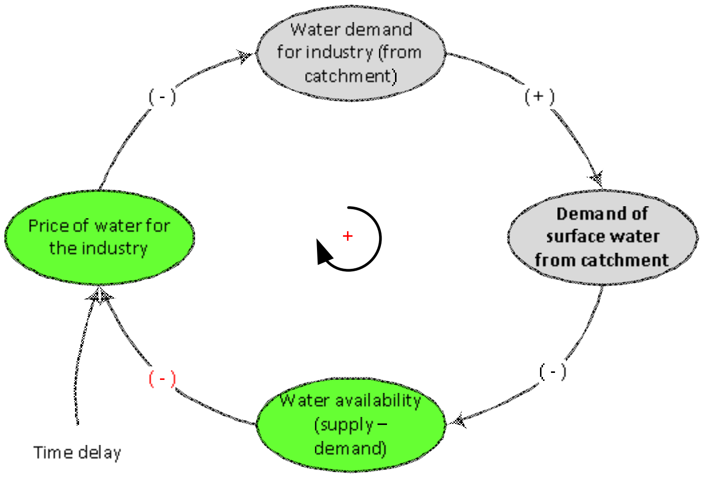

Figure 6. Water quantity feedback loop

Those organics and nitrates are a result of the fact that waste streams are not always treated to the legal requirement. All stakeholders agreed that sometimes waste streams are not treated according to legal requirement by local municipalities, especially those of local municipality. There are many reasons for that (8).

To DWAF the problem can be addressed through monitoring, capabilities and financial resources: "*The political will to monitor is improving quite a lot and hopefully that will improve with time. It is also a mindset of municipalities, industries and so on. But in the end it all comes back to capabilities and money. A huge percentage of municipalities don't have (even) a technician on their staff. They have no technical capacity and capabilities in many cases*".

The local municipalities believe it is very costly to treat waste. Sometimes they run out of budget, and there is the additional problem of polluted water from the mines, namely acid water: "*DWAF has constructed a plant to treat the water, but that plant is not operating as it should. And there is other mine water that is not even treated; its acid water is just running into Loskop. It is going into Olifants River. There is nothing in that river anymore*". They believe sewage is a problem, but mainly due to a lack of resources, costs and awareness of communities.

Provincial government (MDALA) is of the opinion that the probability to be caught and fined is low, and the laws have been very relaxed. Furthermore, the local municipalities do not have the required skills. For example, the operations sections responsible for sewage works do not have an understanding of the scientific theory behind processes.

Sasol also believes that one of the issues within DWAF is expertise and human resource capacity: "*Sasol has that knowledge, so we could work together in a team, or provide funding. We have got one of the best water quality acts. But nothing happened because* *authorities were not in the position to manage the enforcement*". "*The waste discharge system should work. If there are no penalties on it, there is no business for us to do it. All the laws and strategies are in place, we (South Africa) are just not executing the frameworks. It might be competency as the turnover for a position is too fast - before a guy knows what he has to do, he leaves*".

Also according to Sasol it is "way too easy" to get away with polluting the water resources and putting salts down the river, because the polluter does not pay, even if that is a fundamental principle of the National Environmental Management Act. Besides that, in local municipalities there is no proper maintenance strategy as in Sasol: "*You need a certain level of competence, to maintain mechanical equipment. You need a network of people*".

The reuse of mining water is lower than has been agreed between the government and industry because of availability of treatment plants. In practise the reuse of waste streams happens very seldom because of the variety in (mine) water quality and the availability of the plant, industry experiences problems with making the technical specifications for the salts; it is designed for a certain feed composition, and if it changes the system does not operate optimally.

Sasol is member of a number of stakeholder forums, but those forums are failing. Government should participate more in those forum.

<u>Water quantity – Stakeholder perceptions of the identified feedback loop</u>
Multiple parties are responsible for increased water supply and shortage:

- Community - The local municipality is mandated to supply water for human consumption to their area of responsibility and make sure there is enough water.
- Agriculture - If it is not available, the agricultural community cannot obtain access, because it is not economical viable to import water for agriculture from far. The perception is that agriculture steals a lot of water. DWAF is responsible to control it and there is monitoring, and systems are being put in place for legal action.
- Industry - Within affordability limits, industry (and agriculture) can expand as long as they can afford it (their elasticity is very low).
- Ecology - In terms of the national water act, ecology has the first right on water. So DWAF must see to it that the reserve is adequately sustained.

Nevertheless, Sasol is of the opinion that water shortage will hit much sooner than is realised. Sasol is concerned about the availability and the assurance of water supply, which DWAF might not be able to meet: "*The expansion of the Lesotho Highland project should have started four years ago. If they don't supply it, it relies heavily on the strategy of reducing illegal irrigation, which is also everybody's guess how effective that is going to be*".

However DWAF says insufficient water supply is "*unimaginable*", it is "*not an option*". In the northern part, all the available water resources within the acceptable yield have already been allocated. So according to DWAF any increases will have to be thought of in an innovative way. For example: "*the water that we have to supply to the new power stations in the northern part, we will have to pump there, and get from augmentation form other systems, like Lesotho*". "*We can get the water here, no matter what. In the end, ultimately we can desalinate seawater and pump it. But it is going to cost a lot and it needs energy*".

DWAF hopes the price of water does something about the demand, and that it is in control. The impact on water pricing should be immediate; they are supposed to determine the price on annual bases and they have to pass the costs on to the users. However, there is a concern that if the price of water will go up it will not result in less water use, because then the authorities will simply import it. It depends on price elasticity and the industrial users concur. They believe that price change to supply is a slow reaction and they are the last to be affected by a water shortage, because they are 'strategic': "*The price of water is too cheap. That is why people are wasting it and wasting in it. If a company is not going to pay more it is not going to change its behaviour"*.

On the other hand, according to DWAF, it is unwanted that the price of water goes up: "*It will be bad for the private individual. Because whatever you buy that is water based will cost more and also their water uses at home will cost more. So the cost of living will go up. It is good in a sense that the individual will be more efficient. So it has positive spin off, although many people will deny that one*".

CONCLUSIONS

<u>Water quality</u>
The variation of water quality that industrial users in the Secunda complex receives has direct operational impacts such as the cost of water on industrial sites, in terms of the additional treatment costs. The direct comparison between incoming water quality to waste water cost and the cost of ownership of water is known and that increase can be quantified. For example, with the deterioration of water feed, Sasol uses more chemicals to treat the water and they produce more saline. They observe the impact in the increase salinity in the ash water system. A large concern is therefore the impact water quality is going to have on the salt loads. Also, water quality affects Sasol's cooling ability and that affects the carbon footprint and losses.

Water quality should therefore be made predictable. Equipment in industry could handle more pollution, which would reduce the need to use more water for dilution, but it should be predictable, and stable. Sewage works in the public sector also need to improve. Therefore, more human resource capacity is needed within local municipalities and DWAF, as well as more financial resources, especially to support proper monitoring. The private and public sector could cooperate to improve the monitoring.

<u>Water quantity</u>
There is a perception in the Secunda industrial complex that there is a water shortage at that moment, because the community is growing too quickly, and that may affect the price of water for the industry and other user. The complex relies on water transfers, especially for the industrial users; according to DWAF one should only pay for transferred water from other basins if one uses it. However, the industrial users feel that they are paying for other users of the transferred water; more transparency is needed in this regard, for example, the extent of usage by communities and the agricultural sector. Also, there is uncertainty amongst the stakeholders as to when the water transfer from the Lesotho Highland scheme will come to an end. Innovation will then be required, but it is not clear would drive such innovation, and cost implications.

A key issue with both water quantity, and quality, is the price of water that needs to be adapted. However, the price of water does not provide incentives to large industrial users to be more efficient; the current cost is too low and time-delays too long. Also the levies are not an economical incentive for change.

The causes and effects of these and many other issues were well-known (from different perceptions), and solutions to the issues were suggested, by all stakeholders. It was put forward multiple times in the interviews that the implementation and enforcement of stricter policies and laws is needed. It is the effect of such governance tools that still need to be investigated further through a comprehensive modelling framework of the entire system. However, it is very time consuming and costly, and the further development of qualitative models of the most important subsystems is ongoing (8). In the short term these qualitative models will have to be extended to quantify the interrelationships of endogenous an exogenous variables of inland industrial complex systems, to better understand, and influence, the behaviours in the network of stakeholders.

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