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Title of Paper: Developing a Climate Change Toolkit – Lessons Learned, and the Importance of a Spatial Approach

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Abstract

Sustainability represents an issue that is central to the success of organizations. Many organizations are embracing sustainability in terms of reducing their impact on the planet's resources. However, as procurers, designers, owners and operators of infrastructure, we do not always consider whether we are asking the right questions to incorporate sustainability into our new infrastructure. This paper addresses part of SKM's *sustainability into design* initiative, in terms of taking account of climate change in designing sustainable infrastructure.

Climate Change is at the centre of media and political attention at the moment. The Intergovernmental Panel on Climate Change (IPCC) has confirmed that neither mitigation or adaptation can work by themselves – any approach to managing climate change must have both. Even if emissions are reduced now, we will continue to see climate change effects for some time. Adaptation to climate change is therefore a critical part of any future planning.

SKM identified the opportunity to facilitate early adaptation by undertaking a broad-scale assessment of potential vulnerabilities or opportunities arising from climate change effects, to ensure that informed choices can be made at project start-up. The paper discusses how a toolkit was developed and tested using a risk based approach.

Early feedback on the toolkit identified issues with the practicalities of implementing a broad scale assessment of climate risk for each project. Data availability was a critical issue, and we had to resolve how to access data and how to deal with ownership, level of detail, and uncertainty in climate change effects. A spatial approach to gathering and presenting data was found to be the best way to facilitate the understanding of climate impacts within the toolkit, and this paper discusses approaches used, and general issues with climate change vulnerability mapping.

1. Introduction

Over the past 24 months, media and public attention has been drawn to the issue of our changing climate. Although there has been some debate over the causes of climate change, it is generally accepted that the impacts of climate change are already being felt. Therefore we need to start thinking about the longer-term impacts and how we can best minimise the actual impacts on ourselves, our businesses, our infrastructure and our society.

SKM, as a leading engineering and environmental consultancy, undertakes mitigation projects – business managers and project managers are well aware of the issues relating to clean energy, the Clean Development Mechanism (CDM) and greenhouse emissions. We wanted to find a way to make sure that business managers and project managers also fully understood the impacts that ongoing climate change would have on our clients and our business.

2. Toolkit

SKM was in the process of undertaking a major drive to inform staff about sustainability issues, which would (as part of the wider sustainability context) raise general awareness of climate changes and the potential need to adapt to them. However, because of the relative newness of the science and the range of predictions, there wasn't any easily available consensus on all the potential impacts and how they could affect us.

With that in mind, and the objective of ensuring that any adaptation measures had the maximum possible uptake into the projects we do, a proposal was developed for an internal research project to develop a climate change toolkit for project managers. The aim of the toolkit was to provide a process at project start-up to identify whether the project outcome (whether or not it was a physical asset) would be significantly affected by climate change over its lifespan. As a toolkit for Project Managers, it was intended to be incorporated into SKM's project management systems.

3. Business Representation

As a toolkit for all project managers within SKM, the end product must be sufficiently generic to use across the business, although there would be scope to adapt the toolkit for specific market sectors once it was developed. An analysis of SKM's business shows that we have 4 core business sectors:

Table 1: SKM Business Sectors

Core Business Sector	**Subsectors**
Water and Environment	Wastewater, Clean water, Water treatment, Natural Resource Management, Planning and Consenting, Natural Hazards
Power and Industry	Renewable Energy, CDM, Geothermal, Power supply and transmission
Buildings & Infrastructure	Traffic and Transport Planning, Roads & Highways, Rail, Airports, Sustainable Site Development, Ports and Maritime, Buildings, Structures, Project Management
Mining & Metals	Mining, Processing, Mineral Sands

We also have international representation, including in countries likely to suffer early climate change effects, such as the Pacific Islands.

It was therefore important to find a way to make sure that the toolkit would be as useable as possible. To do this, a group of SKM employees were approached and invited to join a working group to develop the toolkit – as the project was being led by New Zealand the majority of staff represented New Zealand, but with inputs from around the world. The working group comprised skill inputs from Wastewater treatment, Wastewater and Stormwater Networks, Stormwater flooding, SUDS, Ports and Maritime, Coastal and Rivers, Natural Resource Management, Forestry, Hydrology and Water Supply, Agriculture, International Adaptation, Power, Renewable Energy, Clean Energy Mechanisms, Buildings, Environmentally Sustainable Development (ESD), Transport Planning, Transport Infrastructure, Spatial and Data Management, Sustainability, Consenting and Planning and Environmental Impact Assessment.

4. Overview of impacts and effects:

The first task of the working group was to review the impacts of climate change on the assets that our clients have. We used Intergovernmental Panel on Climate Change (IPCC) climate change data (Alley et al, 2007), as well as recent interpretations by NIWA (NIWA 2007), CSIRO (CSIRO 2002) and MfE (Ministry for the Environment, 2007, 2008, 2008) to establish the impacts, then brainstormed the effects on infrastructure.

In general, the climate change impacts that we think will affect our clients, from any of the different market sectors are the same – the table below indicates some of the primary ones.

Table 2: Climate Change Impacts and Effects on Infrastructure

Climate change impact	**Effect on infrastructure**
Rising sea levels	Effects on coastal infrastructure, effect on draining times into the sea, effects on coastal floodplain, erosion of coastline.
Increased rainfall peaks	Effect on drainage infrastructure, effect on slope stability and erosion, changing of quantities of runoff vs. that draining to land, effect on storage, effect on ground stability – slips and erosion.
Reduced overall rainfall (in some areas)	Reduced security of water supply, Reduced water levels/flows in rivers – effects on extraction or energy generation, effects on river ecology, impact of discharges into rivers, effect on ground stability – settlement etc.
Increased overall rainfall (in some areas)	Changes in water table. Increasing humidity. Increasing river flows and scour. Effects on stormwater management. Effects on ground stability, local water table, Effects on wastewater networks and treatment.
Increased storminess	Effects on infrastructure in flood or wind prone areas, effects on reliability and accessibility of infrastructure, need for emergency use of infrastructure. Cyclone zone may increase.
Changes in air circulation patterns	Effect on discharges into air Effect on wind power schemes.
Increased vulnerability/ reduced resilience of natural environment	Greater impact of discharges into the environment, or disturbance to the environment. May affect consenting of work.
Changes in temperature and temperature stability	Effect on types of crop and husbandry, pest location, effect on water bodies – evaporation, increased temperature etc, effects on buildings, changes in demand for heating and cooling, effect on people, tourism, leisure activities, health. Effects of higher peak temperatures on existing infrastructure and natural assets. Effects on transported or stored materials, including sewage.

The brainstorming discussion also identified some secondary or consequential effects that should also be considered.

Table 3: Climate Change Impacts and Consequential Effects on Infrastructure

Climate change impact	**Effect on infrastructure**
Consequential effects	
Changing weather patterns may lead to more sunshine hours	Effects on agriculture, solar power, health, demand for cooling
Changing agricultural patterns may affect sources of materials	Availability and cost of construction materials such as wood, changes in transport and associated infrastructure required (including demand for ports etc)
Changing weather patterns	May be more construction weather risk
Increasing temperature	Decline in ‘cold’ tourism and infrastructure demand from cold tourism. Potential increase in greenhouse gases produced by sewage treatment plants.

5. Initial Assessment of Vulnerability to Climate Change Effects

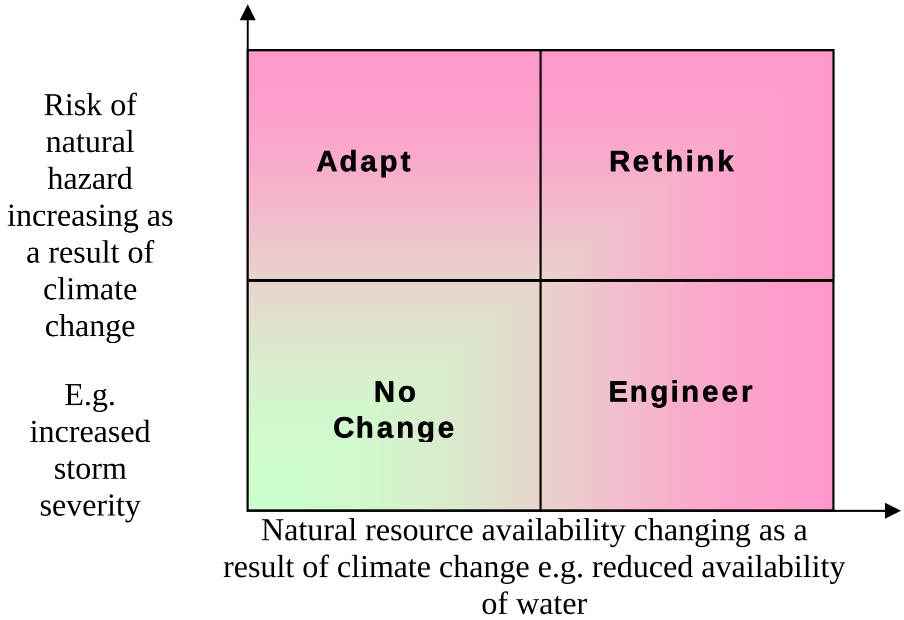
The group agreed that all of the above effects should be considered by the SKM project team, in an initial assessment of vulnerability, before we start talking to our clients, so that we can take a view on the level of risk for the project or client, and therefore justify whether further investigation should take place. On considering the effects, we found they were grouped into 2 over-arching questions:

- Will climate change alter the risk of a natural hazard that the asset will be exposed to?
- Will climate change affect the availability of a natural resource we are relying on?

It is worth noting that there was no presumption made at this stage as to whether the effect would be positive or negative.

The diagram below shows the questions, and possible responses:

Figure 1: Risk based matrix of options to adapt the solution to manage climate change effects



Responses are based on the idea that we can adapt to increasing hazard by changing the asset's structure or location, and that we can engineer processes or systems to better suit variability in availability of resources required.

The initial intention had been to develop a series of questions for project start up (proposal stage onwards), in the SKM Project Management Format. However, we felt that we needed to make the assessment accessible, and visual, so a flowchart was developed to lead Project Managers through the scales of vulnerability.

A flow chart was developed to lead PMs through a step by step process, initially assessing their vulnerability to a change in existing hazards, then assessing the vulnerability to changes in natural resources. The flowchart, plus a series of questions for PMs were distributed among the working group, to test with Project Managers in their region or office, to give feedback on usability.

6. Results of Toolkit Testing Phase

The toolkit testers were asked the flowing questions:

- Are these likely to be helpful/ encourage use?
- Is their intention clear? (in the context above)
- Are these the 'right' questions? What other/ different questions would you ask?

In general, responses showed that almost all infrastructure projects would trigger a climate vulnerability assessment. Key feedback covered 5 main topic areas:

- Terminology – the definition of thresholds to assess whether climate change impacts will affect the asset.
- Scope – there were requests to make the tool more regionally based, to extend to more indirect impacts, to integrate socio-economic aspects.

- Detail – adding more detail on specific areas of concern such as forestry or alpine areas.
- Output – offering the PM more understanding of how the output could be used, for example how to discuss climate risk with clients at project procurement
- Data – the most critical issue coming back from testers was that data is not readily available to quantify most of the climate change effects sufficiently to establish the impact on the asset, although there was generally sufficient data to be able to say that the asset would be affected.

7. Spatial Approach in a Climate Change Toolkit

The working group developed a series of questions as a starting point for initial assessment of vulnerability to climate change effects.

Identifying and understanding vulnerability to impacts like altering rainfall patterns, increased vulnerability/reduced resilience of natural environment, heat waves, rising sea levels, changing wind patterns and flooding, requires access to and analysis of a number of various datasets, and GIS was an ideal solution to present and map existing and future scenarios of natural hazards and effects on the environment (Dow, 2005). GIS applies geography to complex problems and it offers a framework for understanding the relationships and interdependencies of events and conditions (Javed, 2005).

The main goal of the spatial approach in our climate change toolkit development was not to model and predict future climate change scenarios. The goal was to develop a spatial (i.e. geographical data system) template for quick assessment of vulnerability to climate change effects using existing datasets representing present conditions (e.g. floodplains, mean sea level) and datasets describing forecasted scenarios (e.g. projected changes in annual rainfall).

By utilising the capabilities of GIS, we were able to more easily define the thresholds that assessed whether climate change impacts will affect the proposed or actual asset. For example it was easy to establish whether the asset is placed within floodplain areas by spatially representing it on a map with other data layers. If it is, we can establish whether it is within 100 year ARI or 50 ARI year floodplains. Another example of using GIS to more easily define climate change effect thresholds is in assessing the distance of an asset to the coastline. We used the multi ring buffer tool to classify each ring representing the area around coastline, thus creating 50m, 100m, 150m, 200m and 250m zones inland from the coastline, with the 50m zone being the most critical based on CSIRO 2002, MfE 2008.

Various projects/asset-types require combinations of different thematic layers. By introducing more datasets and layers it is easy to increase the scope of impact analysis – e.g. by introducing demographic datasets in the model, further spatial analyses are possible to integrate socio-economic aspects if climate change impacts. We can also bring in available regional future climate change scenarios, once again enhancing the scope of the analysis (http://www.niwa.cri.nz/ncc/clivar/scenarios).

We realised from the start that there is a need for more detailed datasets if we are to get a reasonably clear picture of the interactions of different events and settings. For example, if we want to establish the location of an asset in relation to Mean High Water Springs (MHWS) we need to have an accurate digital elevation model (e.g. LiDAR elevation dataset) and precise regional MHWS levels (http://www.hydro.linz.govt.nz/tides/index.asp).

A spatial approach in the development of a climate change toolkit enabled us to produce visual outputs (maps), thus assisting us in identifying patterns in data that may not be instantly obvious. Introducing aerial and satellite imagery and overlaying it with other datasets further improved visualization of our changing climate.

Geographic Information Systems (GIS) helped us to develop spatial and nonspatial databases to be used as thematic layers and create maps to represent and visualise assessed project/asset in the context of interactions of various events and conditions. The table shows some of the different datasets used in the analysis.

Table 4: Datasets

Potential Climate Change Measure	Useful Datasets
Definition of existing floodplain	Digital Elevation Model (DEM) Floodplain layer
Definition of Mean High Water Springs (MHWS) or sea level line	MHWS table data combined with DEM Coastline layer
Definition of coastal boundaries	Coastline layer Inland coast buffer layer
Definition of land use	Land Use layer
Data on water supply or discharges into water or sea	River, Sea, Lakes, Rainfall layers
Data on soil moisture content or water table level	Soil temperature, MHWS and DEM layers
Data on wind, sun or discharges into air	Sunshine hours, Solar radiation, Wind speed layers
Data on heat fluctuations or increased extreme temperatures	Air temperature, Sunshine hours, Growing degree days

It is very important to point out that we didn't see these assessments of climate change vulnerability as the analysis offering final results; we wanted it to represent means for further analysis and research giving the opportunity to all project participants to explore the vulnerability maps and identify strong and/or weak points. This gives us a chance to improve the analysis taking into consideration their feedback, new information and datasets.

The main challenges in the assessment of climate change vulnerability were uncertainties in climate change effects and the identification and acquisition of suitable information/datasets (Preston et al, 2008). We had to resolve how to access data and how to deal with ownership, level of detail, and accuracy/validation issues. It is often necessary to integrate and analyse data from a range of different sources collected for different purposes. For example, some data may be available for specific local areas (e.g. floodplain zones), but some data are often collected and available at regional, national and/or international levels. This is the reason that datasets come in different formats and are obtained at different scales. It can be quite challenging trying to establish all relationships between data sources and to integrate these datasets in a meaningful and suitable way.

8. Way Forward

Based on the feedback, the toolkit was modified into a 2-stage approach, to incorporate an overview of risk before any analysis or further data gathering was undertaken. Elements were developed to incorporate into proposal and project start up phases. The initial risk assessment, shown below as Table 5 , has been developed to focus the proposal or project manager's mind on what the key risks to the client would be, in terms of the 4-box diagram in Figure 1, and before any significant investment in data is made – Project Managers are directed towards the websites of Ministry for the Environment (MfE), or equivalent bodies in UK, Australia etc for outline data on consequences, or directed towards our own climate change scientists and sustainability practitioners.

Table 5 Initial Risk Assessment: Climate Change Hazard Probability and Resource Consequence Impacts

Hazard Probability	Resource Consequences
Likely/certain over lifetime	High ▪ primary resource affected ▪ asset operation relies on substantial quantities of water ▪ asset required to house or carry people for periods of time ▪ operation cost increases significantly
Possible over lifetime	Medium ▪ mode of operation likely to change ▪ level of service or efficiency changes ▪ operation cost increases somewhat
Unlikely/rare over lifetime	Low ▪ Minor if any impacts

Anything other than low probability or low consequence would warrant further examination within the project. Again, this also enables us to think about whether any of the potential changes would offer opportunities to our clients.

Once we have established whether climate change will be an issue for our clients, i.e. whether climate change will affect the sustainability of what we are proposing as a solution, we can go back to the adaptation matrix shown in Figure 1 to consider:

Do we need to adapt our design for hazards now or later?

- Will our structure or plan need to change to adapt to an increased hazard?
- Will the amendment increase the cost significantly, and if so, can the adaptation features be retro-fitted later?
- Can we make future retrofitting cheaper, or more practical, by making some changes now to enable easier future adaptation?

Will our assumptions about resources still work in the future?

- Can we engineer our processes to use less, or more sustainable/renewable resources? Are there alternatives resources?
- Can we engineer our structures/buildings to use less, or more sustainable/renewable resources. Are there alternative resources?
- Will we need to reduce or clean up our future discharges to air or water, and will we need additional space for the extra processes or equipment?
- Will our proposals be adversely affected by an average change in heat, or by heat waves?
- Are there opportunities for our client's business arising from the changing climate?

These questions can be used to shape the scope, and will help us to deliver projects that will continue to be effective in the future, whatever the future may hold.

9. Conclusions

A toolkit is required for Project managers to easily identify likely vulnerability of a commission to the effects of climate change. This toolkit must be easy to understand and simple to use, to encourage uptake. For initial development, the generic approach across all businesses was suitable.

A geographic approach is needed now more than ever as we are facing numerous challenges. Facing the problems caused by rising sea levels, changes in temperature and weather patterns, population growth, global warming, and so on, will require more information, data and spatial knowledge. GIS and spatial analysis help identify patterns in data that may not be immediately obvious, or where there are wider effects or combinations of effects that again may not be clear from non-spatial data presentation.

GIS is a powerful tool to store, manage, update, manipulate and analyse spatial data related to natural resources, socio-economic parameters, industries, meteorology, environment and utilities. It has wide variety of capabilities for data analysing such as overlaying different themes, defining suitable criteria, ranking and identifying sensitive areas. GIS can be used to prioritise areas for adaptation measures based on their relative sensitivity and ranking. And although there are acknowledged uncertainties in climate modeling and the need for more detailed datasets exceeds available ones, spatial analysis and application in assessment of vulnerability to climate change effects paves the way to adaptation planning.

Detecting and mapping climate change patterns helps with identifying effects on natural resources, populated areas, infrastructure, agriculture, forestry etc, and it can also help with planning climate adaptation strategy.

We must act now to incorporate climate change impacts into our planning and design of infrastructure. The fact that there isn't sufficient data to predict effects fully now is not a 'show-stopper' – we can offer clients the opportunity to future proof work, and build in flexibility for later adaptation, by taking a risk and consequence-based approach. We believe this makes our designs more sustainable, and this in turn makes SKM's business more sustainable.

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