# IESC Explanatory Notes Virtual Masterclass –

# Uncertainty analysis–Guidance for groundwater modelling within a risk management framework – Video transcript

**Interviewer: Welcome to the first of the masterclass series, hosted by the Independent Expert Scientific Committee on coal seam gas and large coal mining development.**

**Okay, let's get going. We've got a really packed couple of hours for you, so I don't want to waste a minute of it.**

**Good morning everyone. My name is Fiona Chandler. I'm with Alluvium Consulting. But my job here today is to help facilitate and host this two hour masterclass. The focus of this one, this is actually the first in a series of three master classes hosted by the IESC. And this one's on the uncertainty analysis, guidance for groundwater modelling within a risk management framework.**

**So if that topic is not what you're expecting, now's a good time to go, or quickly get on the phone and tell your colleagues to join in.**

**I'd like to begin though with an acknowledgement of country and particularly acknowledge the traditional custodians and the owners of all the lands that we’re meeting on today across Australia. And I'd like to extend that acknowledgement to any Aboriginal and Torres Strait Islander people joining us today in this masterclass.**

**I particularly like to pay my respects to elder's past, present and emerging and recognize and celebrate the diversity of Aboriginal people and their ongoing connection to culture and country across Australia.**

**Before we get going, there's a couple of important people that we're going to be hearing from today. So I'll just like to invite them to say hello, and then we're going to ask you a couple of questions as participants. So Chris, could I invite you to say a quick hello to everyone?**

Interviewee 1: Morning, everyone. Chris Pigram. I'm the chair of the IESC and I'm a lapsed geologist.

**Interviewer: Thanks, Chris. We'll hear more from you in a minute.**

Interviewee 2: Hi, I’m Hugh Middlemis, independent at Hydrogeologic, also a lapsed engineer, never have been a geologist.

**Interviewer: Thank you. Luk.**

Interviewee 3: Hi, I’m Luk Peeters with CSIRO in Adelaide. I trained as a geologist, a hydrogeologist still..

**Interviewer: Thanks Luk. Plenty of time for yours to lapse. Peter.**

Interviewee 4: Thanks, Fiona. Peter Baker, Director of the Office of Water Sciences who supports the IESC and I'm both a geologist and a hydrologist and not lapsed at the present time.

**Interviewer: Great, thanks, everyone.**

**So just a couple of words on how you can get the most out of today's master class and how to participate. It's obviously a webinar so there's a little bit constraint. But please make sure you use the Q & A function at any time during the master class to ask a question. We will stop at various points along the way to look at those questions, review them. And if they're easy ones, we'll just get the team to answer in a written sense. If they're a little bit more elaborate, then I'll invite someone from the panel to actually respond to them during that break. So please use that question and answer.**

**Also, if you just want to share an idea or make a comment, or you've got a problem with the connection, can you please use that chat room at any time, we’ll certainly be keeping an eye on that throughout the morning as well**.

**Something we are going to try for the first time is, at the end of the formal webinar, we're going to actually bring everyone into the conversation, if you're able to stay and have a bit more of an open dialogue. We appreciate that all of you have different levels of experience. You've all got some tips and tricks, and perhaps you'd like to ask something a little bit more informal environment. So at 11 o'clock, for about half an hour, we'll be getting rid of the PowerPoint and just enabling an open conversation.**

**And I just like to let you all know that we are recording this webinar, particularly so that others and our colleagues can actually access this information down the track. If you've got any concerns with that, just let me know in the chat room.**

**So let's find out who is actually hiding in the background here and who's in the room. So I'm just going to launch a couple of little quick snap polls. If you'd all just like to take a moment to answer, I think there's four questions. Just to find out who's actually in the room, what's your level of experience or previous exposure to this work around uncertainty analysis? There's no right answers, it just gives us in the panel a bit more of a feel on how to pitch the level of information.**

**We're just interested how long some of you have been working in the field, it's fantastic. If you're new, this is a perfect session on this topic, and just how committed you are with them.**

**I'm going to close that poll now, last seconds.**

**And I'm ending the poll. And I'm just going to share those results with you now. So hopefully you can see those results, we've got, most people coming in from Queensland today. Thank you, but a good smattering across WA, New South Wales, ACT and South Australia.**

**The other was really if anyone, we thought we might have a few people internationally joining us. If that's you, let us know specifically in the chat room where you're joining from.**

**We've also got people with a really deep, diverse background in terms of working in this field. So some people that are relatively new, which is fantastic. But as we suspected, there's a few people that have got a lot of experience in this as well but hopefully, you'll also pick up a few tips and tricks and perhaps in that open discussion, share your, some of your own experience.**

**And again, looks like most of you are at least aware that the Explanatory Note exists, and been able to perhaps use it in some of your work.**

**So that’s fantastic.**

**Okay, I'm going to close that now. And what I'd like to do now is just invite Dr Chris Pigram to give a little bit more of a background information about the IESC. Over to you Chris.**

Interviewee 1: Thanks, Fiona, and, again, welcome, everybody. Delighted to have you participating today. I'm just going to talk you through a little bit of background on the IESC. And if I can have the second slide please Fiona.

The IESC was established by the Australian Government in 2012, under the Commonwealth Environment Protection and Biodiversity Conservation Act, the EPBC Act. Our primary responsibility under the Act is to provide governments with scientific advice on potential water related impacts of coal seam gas and large coal mining developments.

We provide advice to the Australian Government under the EPBC Act and to state governments declared under the National Partnership Agreement. The states that are participants in the National Partnership Agreement are New South Wales, Queensland, South Australia and Victoria.

The IESC can also provide advice to the Australian Government on Bioregional Assessments and research priorities. Next slide, please Fiona.

This is the current committee membership. We are a maximum of eight members. We currently have seven who are appointed by the Minister of Environment. The current committee members are myself obviously, Professor Craig Simmons, who many of you will know and who today would have done this introduction but he's very busy unfortunately. Professor Wendy Timms, next to Craig there. Dr Jenny Stauber CSIRO our ecotoxicologist. Professor Rory Nathan is at the back, in the back row there. a hydrologist. Professor Jenny Davis, who's an ecologist and Dr Andrew Boulton, who's also an ecologist. Dr Catherine Moore, who's at the back between Rory and I has unfortunately left us recently, having relocated to New Zealand and we're in the process of finding her replacement.

If I can have the next one please Fiona.

The Australian Government Environment Minister must seek our advice on any assessment and approval process whether development may have a significant impact on our water resource. This is known as the water trigger under the EPBC Act. We consider all potential impacts on water resources and this includes the effects on groundwater surface water, water quality, quantity, ecosystems and ecological processes.

It's important to note several elements of our advice. Number one, our advice is scientific. It's designed to inform statutory decision makers. We are not regulators, we do not make regulatory decisions and we do not recommend whether a project should or should not be approved.

Our advice is transparent. We publish our advice on our website within 10 days of it being provided to the regulator.

And finally, we're independent. We're appointed as individuals and experts in our field, and we do not represent any group or organization. As you can see here to date, we've provided 137 referrals or advice on 137 referrals.

Next one, please Fiona. The IESC has produced a range of resources to assist proponents in providing the information we need to provide robust scientific advice on a project. These resources include the IESC Information Guidelines and Explanatory Notes. The information guidelines were first published in 2013, updated again in 2015, and then again in May 2018.

These updates aimed to improve clarity and guidance for proponents regarding relevant information and data to support conclusions and environmental assessments. And basically, the updates have been in response to feedback from groups like yourselves.

The guidelines are not prescriptive. It's important to note they're not a checkbox. They provide guidance for proponents on the information needed in environmental assessments to enable the IESC to provide regulators with robust scientific advice on the project's. Explanatory Notes. The 2018 Information Guidelines introduced a series of Explanatory Notes that provide further guidance and describe up to date robust scientific methodologies on specific components of environmental assessments.

Explanatory Notes provide guidance rather than mandatory requirements and the proponents are encouraged to refer to issues of relevance to their particular project.

Explanatory Notes provide a greater level of detail on specific topics than what is provided in the Information Guidelines. The tools and methods identified in the notes aim to help proponents understand the range of available approaches and are designed to be utilised across a range of regulatory regimes.

Case studies and practical examples on how to present certain information are also discussed. The IESC recognises that approaches, methods, tools and software will continue to develop.

The Information Guidelines and Explanatory Notes will be reviewed and updated as necessary to reflect these advances.

Explanatory Notes cannot address all aspects of the top, of a topic of environmental assessments and proponents are encouraged to refer the specialised literature and to engage, engage with their relevant state regulators for grater detail.

Three explanatory Notes have been published on the, on the IESC website, uncertainly analysis, guidance for groundwater modelling within a risk management framework, which is what we're on, going to be discussing in more detail shortly.

Assessing groundwater eco, groundwater dependent ecosystems. This note describes the process for undertaking comprehensive modelling and assessment of the groundwater dependent ecosystems that reviews available tools and methods and gives proponents some guidance on the advantages and disadvantages of each method. And the third one deriving site specific guideline values for physico-chemical parameters and toxicants. This note introduces the use of water and sediment quality management frameworks, assist with the design of appropriate monitoring program from which site specific guidelines can be developed.

A fourth Explanatory Note is currently in preparation, and it's called characterising and modelling of geological fault zones. Public consultation is currently open on the draft note and submissions can be made via the IESC’s website and we would welcome your feedback. The IESC continues to encourage the uptake and adoption of Explanatory Notes as well as the Information Guidelines and we welcome your views on how this might be done.

That's all I have to offer this morning Fiona, I'm happy to take any questions that people might have in relation to the role of the IESC.

**Interviewer: Thanks, Chris. We do have a minute if someone does have a question for Chris, in relation to the broader role of the IESC but Chris is also staying with us for the next couple of hours so there's other opportunities as well.**

**If there's no questions then let's get on to some of the more detailed question, content. And on that note, Hugh, I will let you start off with the first part of the content. Thanks. Hugh.**

Interviewee 2: Thanks, Fiona. Thanks, Chris, for that introduction, it makes my first slide a lot easier. And so just acknowledging that Luk and I are the co-authors of this Explanatory Note on guidance for groundwater modelling within a risk management framework. It’s a long title but the, the risk management framework is a key element of it.

So you can see there in green, some indication of some of the documents that have been published by the IESC and the Information Guideline when it came out in 2013 was informed on groundwater modelling aspects by the groundwater modelling guidelines, the best practice guidelines which said, you know, all the results should include estimates of uncertainty.

So the, the Information Guideline and then the uncertainty analysis Explanatory Note, which came out in 2018. I'd like to point out that not adding to the, the, the red, the red tape issues that we've got. The modelling guidelines already said, you have to do uncertainty analysis Information Guideline, say no, you should do uncertainty analysis and the Explanatory Note is just providing some information around how you might go about doing that uncertainty analysis and what are some key things to look out for?

And that last on the right hand side, industry best practice documents are shown in blue, and that NCGRT report in 2019 was actually the, the front runner in, in the Explanatory Note was published later, though it was actually developed earlier.

And they were all consistent. There's no, you know, I guess there's overlap. There's no inconsistency amongst all those documents. So we're not, not trying to add to the red tape but trying to provide guidance on how to negotiate it, I guess.

So this slide talks about what the Explanatory Note is and what it's not. And those first two lines, you know, say that the, the Explanatory Note is designed to complement the Information Guidelines, the higher level one, and compliment the groundwater modelling guidelines, but it's not a textbook.

And it's not a step-by-step guide to uncertainty assessment and that's because, that’s really unworkable given this, you know, multitude of methods, different project contexts, different project risks. So that's why we don't call it a guideline, it's, it’s, it’s an Explanatory Note. It helps, it helps outline how you might negotiate that minefield.

On the last two lines, essentially, the, the guide, the Explanatory Note is, is integrated within a risk management framework. That's, that's important to us because it, it helps us understand what level of effort we should apply to the uncertainty analysis, as you know, can be very onerous. And if you integrate your uncertainty analysis within a risk management context, then that allows you to figure out exactly how much effort you should put into it. And the Explanatory Note does outline a workflow process and provide some examples of methods, but it doesn't identify a single preferred method. It doesn't preclude the use of, you know, any, any techniques provided you can justify it and provided you've agreed that with the regulator, noting that the IESC is not a regulator.

And the last, there's two more things to say one is, given the risk management context, the Explanatory Note does say that every project requires a qualitative uncertainty assessment as a, as a minimum. And if it's a high-risk site, then you need a quantitative uncertainty analysis. But even the most comprehensive modelling uncertainty analysis study can't rule out the potential for unwanted outcomes. I think I've stole it from John Doherty.

This slide is really designed to show how an uncertainty analysis although some people might view it as an overhead, it really is something that can help a project, can help with risk assessment, it can help identify the effect of risk treatments, it can help with reducing uncertainty by identifying ways to gather data. And the results from uncertainty analysis can help communicate uncertainty and risk. That flowchart is, was done by Glenn Walker, and that's also in the guideline.

So it's important to get a couple of definitions out there. So risk is defined as the effect of uncertainty on your project objectives, as the definition, is quantified or characterised as a function of consequence and probability. Or if you like, impact and likelihood some people thought about.

We'll, we’ll come back to these points as we go through this slide and we can take questions on it later. But essentially, because the level of uncertainty analysis effort should be commensurate with the risk, that means that you've really got to do a, a qualitative uncertainty analysis upfront or preliminary, sorry, preliminary risk assessment upfront, so that you can identify what are the key risk issues, and that risk, risk assessment should consider in a causal pathways for impacts.

So you may be able to treat that qualitatively and identify that there are no causal pathways for impacts. An example of that was the Cooper Basin bioregional assessment, which confirmed that for a particular project that we're looking at, there were no risk pathways. And so they stopped at a conceptual modelling stage and didn't go through even to a numerical modelling stage. That's explained in the Explanatory Note. So it's important to do that preliminary risk assessment to set the context and decide how to proceed.

There’s a case study in the Explanatory Note, this one's from WA, from Pilbara mining areas. See, the, the horizontal black line is the water demand for this project. The columns are the, the dewatering, that's available. So the base case is shown in solid colour, and different colour for second project coming on board and then the dashed lines are the range of uncertainty analysis results.

So that shows at certain times, you've got a deficit of dewatering to meet the water demand, so you're going to have to have another borefield somewhere. And in other times, you've got an excess of dewatering. So you can have a disposal problem. Consultants love that both types of problem, but the case study does help show that uncertainty analysis can identify issues and solutions for your, for your project.

We use this from the iron ore field because we couldn't find an ideal case study to present from, from the coal industry. Luk may have more to say about that later.

In the Explanatory Note provides a workflow on, on an uncertainty analysis. So we don't give you a step by step guide. Although there are steps in that workflow, and that workflow doesn't show all the iteration loops that are involved in modelling and uncertainty analysis, but it does sort of outline, there's three main phases. There's a problem definition phase, a modelling phase, and a predictive uncertainty analysis phase and the consultations require that each of those steps as we go through it. If we break that down a little bit, stages one and two, if you like, is the problem definition in the modelling phase, they, they're crucial.

The need to consider, as we've said, the, the potential impact pathways, the hydrogeological understanding and the conceptual model, and the preliminary risk context. And sometimes you if you can treat the risks, then maybe you don't need to do modelling and uncertainty analysis if you treated them carefully.

Having defined the problem and figured out, you know, what are the quantities of interest in what are the causal pathways for impact, then you can design and, and build a, a model with an appropriate balance between complexity and simplicity, so that you can actually implement that uncertainty analysis. I'm not going to step you through each of those steps.

And then step three is actually the predictive uncertainty analysis. And that workflow really is kind of, you know, it's kind of tilted towards to having to do a quantitative uncertainty analysis, but it, it does outline roughly how it goes.

The Explanatory Note was at sometimes to explain a couple of myths and there's a, there's an issue around the model covenants level classification, it's in the Australian groundwater modelling guidelines. 2012.

The Explanatory Note provides an update to that. And essentially, it's our position that it's just wrong for anybody to suggest that a particular model needs a particular confidence level. That's just wrong. In the Explanatory Note, or even in the modelling guidelines, they say that the model should quantify its own uncertainty, rather than relying on this competence level classification that's in, that’s in the modelling guidelines.

So we're using that competence level classification in the Explanatory Note. And we're presenting a different way of, of doing that, essentially by coming up with, with a sort of a weighted scores method. So if you look at the green ticks, here, some are solid green, some are light green, bit of a tilt then, might have done that might have not. And they greys, you know, that's been addressed at a higher level, the orange crosses, you haven't got to that level on that particular attribute.

So if you look at this, the greens, you know, there's a wave of greens in class three, there’s a smattering of greens in class two, you'd call that a class two slash three model. But you still have to justify why that's the case.

I've seen, I do reviews as a core part of my work and I see a lot of people suggesting that a, a class model is not good enough for anything. Well, that's just not true. It's not true in the modelling guidelines in 2012. It's certainly not true in this Explanatory Note.

Another issue was about fitness for purpose, excuse me, ground modelling guidelines lacks a definition on what is fit for purpose. But it does leave some guiding, guiding principles in that. And, and so if you, if you grab those little tips out of the modelling guidelines and try to come up with a, with a definition, you get something like this, that you have to define the study objective or purpose in specific terms and measurable terms, along with the management objectives that you're asking to address. And the complexity must be assessed and, and appropriate for the purpose objectives and resources. That's a little bit circular, those two things, but you know, these are just words out of the eight, out of the groundwater modelling guidelines that give us a clue to what the definition might look like.

And there's other things that you should have negotiation on model complexity and overall resources available to the study should be, should be understood.

So we, we decided on the expansion note that we would provide a definition, and, and we have fit for the purpose and it's, and it's a groundwater model must be designed to be fit for purpose of providing information that uncertainties in conceptualisations, and simulations, but in a way that allows decision makers to understand the effects of uncertainty on the project objectives, that’s that risk, standard definition for you know for what is risk.

So, that's the definition that we're presenting here is really designed, it's not, not for all models, although I imagine people like John Doherty, and others would say it, it should be a definition of fitness for purpose for all models, because all models should do uncertainty analysis. But it really was really, in our mind really focus on fitness for purpose for uncertainty analysis.

Now, because there are multiple quantities of interest that makes it complicates an uncertainty analysis, and Luk, will talk about that a little bit more in his session. An example is a model built, designed and built for mine dewatering is not necessarily suited for assessing the impacts on groundwater dependent ecosystems. It may be but it's not necessarily and you might need more than one model to do a full assessment.

That's getting less so these days, with improved the software, but it's an issue that, that you need to consider is, is what is your key model purpose, and design and build your model for that work, you might need more than one model for your impact assessment overall.

In the Explanatory Note, we provide a sort of set of minimum requirements. If you like, we don't quite look like that but that's kind of what they are. All projects require a qualitative uncertainty analysis, and that explores how assumptions affect the simulations in very simple terms. High risk projects need a quantitative uncertainty analysis. And the level of effort should be commensurate with the risks.

And so it means your preliminary risk assessments I said that, and in particular, the methods apply and have to consider the development stresses, usually dewatering, depressurisation, and the causal pathways for impacts on water resources, assets.

So there, they’re the core things and things that flow from that, you need an explicit objective definition, you need specific quantities of interest, you need a balance between simplicity and complexity, and so on.

And Luk, we'll be talking more about that. If we take a step back for a minute, and just look at what's in the Explanatory Note, it was interesting that when you look at the key guiding principles that we came up with, they, they group around two principal things there’s one around communication.

So what are the specific outcomes? What, what, you know have consultation, justify your methods of assumptions, write a report that's opened in a minimal scrutiny review. That's all about communication as a large part of this Explanatory Note.

And then the other bit, I've called uncertainty analysis, integrated within a risk management framework, because the resources and the level of effort should be commensurate with the risks. And you can use treatments to mitigate those risks. You don't have to use uncertainty analysis.

And then you need to provide outputs and help decision makers make decisions under uncertainty make sure the models balanced by design between, it’s actual appropriate complexity and appropriate simplicity. So we, we just thought that was interesting. When we got to the end of it, we just looked it up. And that's the way it came out.

And this is my final slide. Before I throw to Luk. We were asked by, by Peter Baker, he's listening in, yes he is. To provide a sort of a fatal flaws review checklist and we didn't, we didn’t like to do it but we, we came up with one and essentially, we took those guiding principles that we, we set out in the Explanatory Note and we asked a series of questions around those guiding principles. And once again, it focuses on that workflow process and the methods. I've just mentioned what those things are.

So you could use this as a checklist and a checkbox for your internal quality assurance, if you like just to make sure that you've addressed everything but really, if you present this, this is a check book, check box, it will get thrown out.

What we're really asking you to do is present a report that addresses in a long form way, those issues that are raised in that fatal flaws, review checklist, you know, have you justified your assumptions and presented information that addresses those key points in that fatal flaws, review checklist? Luk might have a nuance on that interpretation when he takes us forward, but that's, that's largely my presentation.

**Interviewer: Thanks, Hugh. And we've just got a minute or so to see if there’s any questions.**

**So just giving people a minute to think about that, based on what you've heard about the, the content and the background to the Explanatory Note.**

**No. All right. Well, Luk, let's keep digging a bit deeper then and please people, you know, remember that Q & A is there, we got to stop again in a little while or just in that chat room, if you'd like to post something perhaps, for a little bit more discussion. Thanks, Luk. Over to you.**

Interviewee 3: Great, thank you Fiona. So yeah, picking up where the, where Hugh left us with, with a fatal flaws checklist and yeah, reiterating that, that message that, it is a checklist, but what I want to try to do in my part of the presentation is unpack that checklist and really go through the reasoning behind all of those checks. What we are actually looking for, what is the information that we are, that I would be, what I would see like to see in when doing uncertainty analysis and groundwater modelling. So I know there's a lot of arrows on this, on this slide.

What I'm trying to do here is just showing that those, that fatal flaws checklist is kind of grouped in again, by three themes. So the, the orange arrows are about that communication, that very important part that Hugh already mentioned as well is having that the, the reporting. It also is about communicating between two different parties involved to proponent, consultants, regulators and stakeholders.

The red arrows they're pointing to defining your project objectives, your quantity of interest, your scenarios. Again, this goes back to what's already in the groundwater modelling guidelines, as Hugh mentioned.

But in the bill, the bulk of the presentation is about those green arrows. And I'm not about to give you a step-by-step technical discussion on how to do an uncertainty analysis. What I rather want to spend some time on is discussing the different trade-offs that you will encounter when designing a groundwater model when designing an uncertainty analysis, and how to find that balance between simplicity and complexity within the constraints of the projects we're working in.

In the Explanatory Note, we spend a bit of time on emphasising how important that is, is that early communication between the involved parties, in setting up the groundwater model study to set the goalposts of what that model study needs to achieve. And what I'm trying to do with this slides here, if we take that concept of risk, if you look at the different parties involved, each have their own specific risk in a project proposal. Obviously, for a proponent, the main risk they're looking at is getting approval for the development and the main risk is not getting that approval.

If they cannot show that there is limited or no environmental harm. Regulator, they are looking at exactly that environmental impact. But they are looking at within the confines, within the boundary set of their jurisdiction, within their legal framework.

Stakeholders very much looking at the same issues, the environmental harm, or the risk to their, their assets. But for them it's, let's say more personal, that's more local. It's about their bore, it's about their population of koalas.

And a consultant, as such, the consultant building that groundwater model doing uncertainty analysis, often, there is no direct risk for that, for them in that proposal, except for, of course, the contractual or reputational risks, should they not do a good job.

But one of the main roles or key roles I can see for consultants here is trying to navigate that, that conversation between the three parties and making sure that your groundwater modelling study, your uncertainty analysis, addresses the concerns of all of those parties and finding that middle ground.

And again, I know this is very, it's much easier said than done and that's actually, it is a really hard parts to get right and it is very, but it's so important in the overall framework, it's the starting point because it's, this, that's the point where you're setting your project objectives.

So I like to make the distinction between project objective and the quantity of interest. So your project objective is pretty much the high level objective of what you want to achieve. In this case, we're mostly in for IESC matters, we're mostly looking at environmental impact assessment so it's really about those high-level questions. are the impacts of this proposed development acceptable, can it be avoided or mitigated, does it need to be compensated.

Those are kind of the high level questions, the project objectives. Now the quantity of interest, is how is the groundwater model going to answer those questions? What are the outputs of the groundwater model that you need to address that, that objective and a big part of that is, of course, specifying what the scenario is or the scenarios that you are going to evaluate.

Again, this is material that is covered in depth in the groundwater modelling guidelines, it is crucial in any groundwater model report. The reason I'm emphasizing this is, the more explicit you are at the start about this quantity of interest, the easier it is to set up and discuss all of the trade-offs in your groundwater model design and uncertainty analysis. So just before I dive into that, what you, what I really, what I like to do when I'm doing these kind of studies is be in excruciating detail explicit in, what are the state variables we're looking at, is it a groundwater level, is it a flux, is the concentration, what is the spatial extent, is this just a point location, is over the entire area, what is the timeframe, is it an average, is it a maximum, are we talking about an absolute quantity of interest or a relative?

So an absolute could be a groundwater level threshold or a salinity threshold while a relative quantity of interest might be, for instance, a drawdown where you make a difference between two scenarios.

And obviously, what are the stressors that you're putting on, what you are going to simulate, especially in your future scenarios. Now, those can be stressors, stresses associated with the development as such, so your pumping rate, your drainage level, these kind of things, but also external things like climate change.

And especially if you're doing a, a relative quantity of interest, you need to establish what your reference condition is. So if you are going to run a baseline scenario into the future, you have to spell out that baseline, as well as the development scenario and how you're going to do that.

Difference, you know. Anyone who has been doing groundwater models is probably me explaining you how to suck eggs. But I find it always, the reason why I'm putting so much emphasis on this is it makes those stories and justifying your assumptions so much easier down the track if you can establish that quantity of interest from the start.

So climate change, for instance, is one of those stressors that's often comes back and commentary or advice from IESC, on how to deal with it. Now, when I'm thinking about climate change, or whether or not to include it in the groundwater model, it all comes back to that, doesn't matter for my, for the quantity of interest.

If the quantity of interest is sensitive to boundary conditions that may change to climate change, so things but, things that are sensitive to recharge river stage, ET, then obviously, climate change is going to be something that, that needs to be represented, especially if you're looking decades into the future.

But another part to think about is, am I dealing with an absolute versus a relative quantity of interest? And that means difference between the groundwater level threshold for instance, depth of water table cannot be less than 10 meters at this location, or a drawdown threshold. You can't have more than two metres drawdown at a specific bore. These are very different things.

So if you work through a bit of a couple of examples on this, if the quantity of interest is mine pit inflow, well, that's a water balance question, often very sensitive to recharge so if that is your quantity of interest then considering climate change is definitely something on the cards.

If your quantity of interest is purely a drawdown, provided, your climate change recharge scenario is the same in both your baseline and your development scenario, those effects often cancel out so climate change might not be that essential in representing groundwater dependent, for groundwater dependent ecosystems, it becomes much, a bit more difficult and I’m more than happy to refer to the upcoming masterclass on GDEs, about how you, how you find and select those kind of thresholds.

But for those ones, it's going to have a conversation with the ecologist what is, what is important for a particular GDE, what is the kind of quantity of interests of your groundwater model relevant for it and in function of that you can then have that conversation on does climate change matter for this prediction? And once you've established that, that's, again, which climate change scenario you're going to use, how are you going to implement that?

Again, that's a conversation you best to have with your regulator and stakeholders as well, just to going to have that agreement upfront and we put this reference in there just a bit of information or an example from Victoria, on how to deal with climate change in groundwater models.

So, slightly difference that in the fatal flaws checklist, there is a line there about potential bias, and how to acknowledge that and represent that in the report.

Whenever you do a groundwater model, whenever you do an uncertainty analysis, you will have to make subjective choices. There is no textbook, there is no recipe that will give you exactly what you need to do for each situation. And of, more often than not, you don't have sufficient data to make an objective goal on what the right choice is.

So regardless of the project you're in, you'll have to make those choices and when you have to make those subjective choices, there will be unconscious bias. Again, that's not a nefarious thing it’s just, it reflects your experience, your personality. If you ask me to make a groundwater model of an area and you ask, Hugh to make the same model of the same area, I guarantee you will get very different results, very different models. I’m not saying that one is better than the other. It's just, it's difference in experience and approach that will be in there.

The only way that you can account for that is to be open and transparent in the discussion of those choices and to provide a reasoning why you went for a particular path.

There is, however, one kind of bias that is widely accepted, especially in impact assessment and that's the precautionary principle. That's where you're on purpose biasing your results to make sure that you select, you make choices so that the potential impact is over estimated.

It's a very powerful thing if you can do it right, if you can show that you're biasing your model to over predict and the impacts are less than what is considered acceptable, then you've got a very strong case to say that the project is not going to have an environmental harm.

However, demonstrating that is not always trivial, especially if you have more than one quantity of interest. So bit stylised diagram here on the right, but consider you'll have a proposed mine dewatering project and there's two quantities of interests, streamflow depletion and drawdown. They both depends on your hydraulic properties.

Now if you want to maximize overestimated drawdown prediction, you have to select the lower transmissivity values. However, if you want to have the maximum or over predict the streamflow depletion, you have to pick the maximum transmissivity values. So with a single model, you'll never be able to overestimate both.

Again, you have to kind of do that discretion and be clear about if you went for a particular overestimation, acknowledge that it might not be overestimating other quantities of interest and again, expect this is a very simple example you can imagine for more complex situation that is not always trivial to demonstrate this.

That was pretty much my introduction, the communication, setting up your objectives and dealing with bias and this isnow, getting to the bulk of these trade-offs. What, what are the things to consider in setting up your groundwater model and setting up your uncertainty analysis.

So the definition of uncertainty analysis I'm using it's very broad one, but basically has three components. It's about estimating or providing the range of model outcomes that are consistent with what we know about a system, and honour historical observations of state variables.

So I'm representing that here in a triangle just to illustrate that within the boundary conditions over any project, we have a limited timeframe, we have a limited budget, there are trade-offs that we have to make in achieving each of those components of an uncertainty analysis and it's really finding that, that balance between those three.

So if we unpack that a bit more, representing the knowledge, what we know about a system in the groundwater model that's basically translating our conceptual model understanding into a numerical model.

Now, excuse me, that's about representing processes and structure into a model. The more processes you put in there, the more detailed your structure, usually results in models that take longer to run.

Matching historical observations. In order to match those observations, we need parameters, the more parameters that you can tweak that you can play with, the easier it will be to match your observations. So that can be representing spatial heterogeneity but it can also mean parameterising boundary conditions, for instance, you recharge your river, your surface water groundwater interaction. Of course, that comes with a cost, the more parameters that you need to include in your calibration, the longer it'll, your calibration will take.

Representing the range of outcomes. If you want to really, if you're not just interested in the mean value, or the most likely outcome, but you want to have like your 98th or 95th percentile, that means that you need, spend more time sampling your parameter ranges, which increases the number of model ones that you need.

So you will need to be finding that kind of trade-off on how am I going to spend my computational budget, the model runtime that I have available? How am I going to divide that between those three components and just illustrating that for a couple of hypothetical examples?

Let's say you're dealing with a greenfield situation where there's no historical data. We’re asked to doan impact assessment. I would bias or moved that to making sure that the model captures what, what we do know that the process and the structure but rather than trying to do a calibration, I would spend more time doing sampling the prior information, doing more model runs characterising the range of outcomes.

However, if you're in a brownfield situation, think, for instance, an extension of an existing mine, there is historical data available, you've got a pretty good understanding on how the system works and what are the important parts, what you can simplify and you can constrain your, your parameters with historical data.

That's where I wouldn't spend, I would try to simplify the model where possible, but in, at least in terms of which processes to consider, but spend more time trying to get those historical, matching those historical observations and balancing that with sampling the priors.

I was looking at it for a couple of examples where getting that range of model outcomes was less important. One of them, for instance, could be when you're testing a hypothesis, for instance, is a fault permeable. Consider, for instance, a pumping test across a fault.

In that case, you might not be that interested in the range of outcomes, you're more interested in representing that fault, and making sure that you match the results of your pumping test so that you have the most likely outcome, whether or not that fault is permeable.

And finally, when bug matching an example of where, where it's only about knowledge. To me, these are things like problem scoping, where you're at the very early stages of a project trying to figure out how, how far do I need to have my model domain, is this really going to be an issue, sometimes with some very simple modelling, some analytic solutions, even with some extreme parameter combinations, you can get a feel of how big the problem is, and whether or not more detailed modelling is required.

That brings me to the kind of next trade-off is which parameters to include, again, that is very case specific but it comes down to the sensitivity analysis and parameter identifiability. Now, the difference between those two concepts, sensitivity analysis for me is the, the more generic term, it's where you look at both whether which parameters your predictions are sensitive to and which parameters your observations are sensitive to, while parameter identifiability is just limited to which parameters can you constrain with your data.

For me, it's almost self-evident that in your uncertainty analysis, you want to include all the parameters that your prediction is sensitive to. If, of those parameters, the ones that you can constrain by data, so the parameters your data are sensitive to as well. Those are great, because you mean, that means that through calibration, you're actually reducing the uncertainty in your predictions. For instance, consider making predictions in alluvial system where you have hydraulic conductivity, you have observations of groundwater levels, based those observations can constrain your hydraulic conductivity in the alluvium and your prediction of drawdown is sensitive to that as well so you can actually reduce uncertainty.

However, we often find ourselves in a position where the quantity of interest is most sensitive to parameters that cannot be constrain, often been a situation where we're trying to do, where the prediction is mostly sensitive to, for instance, hydraulic conductivity of a coal seam, and there's no data to constrain that.

Those ones are incredibly important to represent well in your uncertainty analysis because those are often the biggest drivers of uncertainty and your calibration is actually not reducing uncertainty in those parameters.

There's also a lot of parameters that your quantity of interest will not be sensitive to so whether or not to include those.

If your, if you, if your data is not sensitive to those parameters, don't include them. It's a waste of time and money to do so. However, if your data are sensitive to that parameter, it's probably worthwhile to include it. The best example would be, again, that alluvial system, your prediction of drawdown might not be sensitive to recharge. But if you want to estimate hydraulic conductivity, you need your recharge value as well. So if you're not in, if you would fix your recharge value, you might actually bias your hydraulic conductivity and then affect your predictions of, and actually make worse predictions in under estimating the uncertainty in your predictions.

I've been talking about this in the context of parameters but this also goes for processes so you can actually go through this same thing about whether falls or climate change is important for your predictions and whether or not you can inform it through your data.

In some cases, you can figure this out from first principles, like the example with recharging hydraulic conductivity, that's something that's just textbook information on how, based on the groundwater flow equations. However, in complex models, this might be, this will probably become part of the output of your sensitivity analysis of your model.

Then comes to the kind of the next when you've selected those parameters, when you figured out what your object, quantity of interest is, it's which uncertainty analysis technique to choose.

There's a lot of techniques out there and the Explanatory Note, we tried to group them together in three broad classes. So scenario analysis is where you have, where you just have your calibrated model, and you increase one or two parameters by a predefined number, or decreases and present those numbers.

It's very simple to do but what it does not provide you is an idea of the likelihood of those outcomes so whether you don't know whether to adding 10% to a parameter, whether it is extremely unlikely or very likely.

If you want to have that likelihood information, the next step up is doing deterministic modelling with linear uncertainty quantification so your calibrated model is considered the mean of your prediction and through linear uncertainty quantification, you can actually calculate in a standard deviation and get a distribution based on that.

It takes at least two model runs per parameter to do this kind of analysis. It works really well but it makes some very strong assumptions on how linear your model is, and how wide and whether your parameters are normally or not normally distributed.

If those assumptions, if you can't justify them, if they don't know, these conditions are not satisfied, the next step up is doing the stochastic analysis where you basically are doing a random sampling of your parameters and you can do, with selecting the ones that are matching your historical observations.

The cost of that, of course, is the number of model runs required. So you need quite a lot of model runs to do this properly and, moving through, that becomes a kind of an open, it's a kind of a hard question to answer on how many model runs do you actually need for a model to do it properly. I'm not going to walk you through the, the math behind it but more than happy to do that offline afterwards.

The graph what I'm showing here is trying to figure out a question, the question. If I do random sampling of a group of parameters, how many samples do I need to make sure that there's at least one sample where all the parameters are greater than the mean?

So I'm picking that greater of the mean as an example of that would be representing an extreme parameter combination that would might, that might lead to an extreme impact prediction and that's something especially in impact assessments is those extremes that we might be interested in.

If your model has five parameters, a hundred model runs, you'll be very, it gives you almost 100% certainty that you'll have at least one of those model runs have all parameters greater than the mean but as you can see it raises, increases exponentially and if you've got a model with 10 parameters, you're looking at, at least 1,500 model runs to be 95% sure that one of those has all parameters greater than the mean.

Now, that's a slightly worrying graph because I know in most groundwater models, you'll have dozens, if not hundreds of model parameters, so that would mean you would need, need models, you need millions of model runs to really sample everything.

What I found in practice, however, is that when I do sensitivity analysis of groundwater models, there's usually only a handful of parameters that are dominating the uncertainty. So that's the graph on the right, it's from a groundwater model we did for the Bioregional Assessments a couple of years ago. We had, in this case, 38 parameters, and three different quantities of interest and the blue bars are the parameters that were really sensitive that contributed to the uncertainty.

You can see that each quantity of interest only had maximum five parameters that are really driving that uncertainty and if you combine all three of those, we got about 10 parameters that are really important driving the uncertainty in our predictions. So in this case, we ran the model 10,000 times, which gave us a level of confidence that within those 10,000 model runs, we did have, we did cover the extreme values reasonably well.

Again, a bit lag and changing between the slides. So in this slide, I’m, I'm trying to summarise that information and looking at how the difference, the different uncertainty analysis techniques, how they sit with respect to those three components of uncertainty analysis, how well they do in achieving those.

So Hugh in the start mentioned the quality of uncertainty analysis and to me, that's the only way to really show that what you're doing is consistent with the knowledge, what you have, it's where you document and explain your choices, and show that how you have set up your groundwater modelling uncertainty analysis, how that is consistent with what you know about that system.

The groundwater model approach and uncertainty analysis approaches as such, they're always built around some kind of metric, for instance, your root mean squared error and it's really hard to find a good metric that captures everything about what we know about a system, so none of them will actually guarantee that your model is consistent with knowledge, we all know the examples of getting great RM, root means squared numbers and having an absolute shocker of a model.

I put a couple of footnotes on there, so especially for the automated techniques like linear analysis and stochastic analysis. If you're able to find the right, a good objective function, it can be incredibly powerful. Manual calibration, and scenario analysis doesn't give you that, doesn't give you that guarantee that you'll find a good, the optimal solution but because you're only dealing with a handful of model results, you actually have the opportunity to look at time series to look at maps, look at the water balance so you can actually do a more in-depth analysis and see how well those things correspond with what you know about the systems, so that's kind of that soft data, it's much easier to evaluate if you only have a handful of models.

So reproducing historical observations, as I said, the automated techniques, they are designed to do that. They can guarantee that they will find you the minimum of your objective function and they are very good at that. Scenario analysis has no guarantee whatsoever that you actually, that you have found the best fit to your data.

Now coming to that final part on capturing the range in the extreme values.Linear analysis, what I found is that often those strong assumptions about linearity and whether or not your models, your parameters and predictions are normally distributed, they often holds closely calibrated value to the mean of your distribution but the further away you go to the, to the edges and the extremes, the more tenuous those things come become, and those assumptions are often not valid anymore so I wouldn't, I wouldn't recommend using that if you're really interested in a 90th or 95th percentile, and that's where for instance, stochastic analysis is much more appropriate.

But again, this is a qualified yes in this table because you still need to show all the things I mentioned before that you have covered all the relevant sources of uncertainty that you have that, that you know which prior parameter distributions, which ones are constrained by the data, so which ones you actually have been able to reduce uncertainty and which ones you're actually unconstrained and relying on your prior estimate of what the ranges are and then that final bit of slide I just showed about that you've done that, the sampling that you've done is sufficient to actually cover off on the extremes of that range and it also means if you're interested in your 90th percentile, that will require less model runs via 95th or 99 percentile.

Now capturing the range and extreme values with scenario analysis, I put that as a qualified yes as well because if you can show that the particular parameter combination that you chose is extreme, or would lead to an over, an extreme prediction, then one single model run can actually give you your worst case analysis.

That is a very efficient way of doing things but it is very hard to demonstrate that those particular values that you chose, that they are indeed, the extremes, and that they will lead to a maximum impact prediction.

So tying that back to the examples I gave earlier, so number one was the greenfield, the greenfield situation with no historical data, so that's where I would go for the stochastic analysis with unconstrained prior distributions, and really focusing on sampling that extensively to get that full range, while for a situation where you have historical observations, and you know a bit more about how your system works, that's where you can look at more of those hybrid techniques.

For instance, yes, the iterative ensemble smoother would be a good solution in that kind of context to give you that balance between sampling your prior distributions and matching your historical data.

For the interpretation of a pumping test around a fault, that's where I would go purely for linear analysis and you're looking for that, those most likely outcomes, the average conditions.

Well, finally, for this kind of scoping exercise, I wouldn't bother with any of the more advanced techniques and just go with a scenario analysis with an extreme value, especially if you're using just an analytic solution, there's only a handful of parameters, it's much easier to demonstrate that you are conservative.

But for all four of those cases, I would complement that with a qualitative uncertainty analysis, explaining in detail why I'm making those choices, not just why I'm making those choices, but also how it will affect the model predictions. Which basically comes to the, the reporting bit, it's, and again, this is, most of you probably aren't aware that impact assessment and risk communication is about trust more, as much, as it is about the science and the facts that you're presenting.

It's really hard to gain trust, very easy to lose trust so especially when it comes to those subjective model choices. Those are the ones that can undermine that trust in the communication so I'm not sure whether it works well but the approach I've been trying to do in my own work is to really own those assumptions and choices and shine a spotlight on them, no try to hide them away somewhere in the middle of the report, but really summarize them and shine the spotlight on them and be very open about why I made a subjective choice, and how it might affect them model findings. I’m pretty much inviting reviewers to disagree with me, but at least then you can have that conversation, you can have that discussion.

On a very practical level, what helps with the transparent and open reporting is scripted model building. So we've started doing that in the Bioregional Assessments and I know it's a very big part of the GMDSI initiative, especially with the Python packages, flow Python by Mu that are now available.

It means that you can, the entire workflow of building a model and doing the uncertainty analysis, you can capture in those kind of workbooks, which means that afterwards, somebody else can look over what you've done, but also you can repeat your analysis and it gets that kind of full workflow of where your data went in, how you transformed it and how you used it in your model and that's so important to get to allow that be reviewed to make your modelling amenable for, for scrutiny.

And this is going to be just, I’m getting to the end of my, my slide pack and spend some time a couple of weeks ago, looking at the IESC advice, 11 most recent cases IESC published on their website and I looked at mostly the ground, those groundwater model reports on how they deal with uncertainty analysis and what are the comments in the IESC advice on with respect to uncertainty analysis.

I picked 11, pretty much that was how much time I had, I didn't have time to go any further but those are all in the last two years so since the Explanatory Note came out.

Of the 11 that I looked at, there were six that did a stochastic analysis. One the linear analysis, there were two that only did scenario analysis so just changing parameters one at a time, and there were two that have no formal uncertainty analysis.

I must say there were four of those of the stochastic ones that kind of went for a hybrid approach where some parts of the, some predictions were, or parameters were dealt with, through the stochastic analysis, and then other parts through a scenario analysis.

I'm not too much of a fan of that kind of hybrid approach because it really, it sets you up to be inconsistent in your results and becomes a really difficult story to tell so I would really recommend to stick by, to one or the other, just, again, makes it a much clearer and cleaner story to tell.

What I found interesting was that, there was a lot of people who did parameter sensitivity or parameter identifiability so eight of them did parameter identifiability, figuring out which parameters could be constrained by the data but only four of them actually looked at which parameters were important for the predictions and those four were only, were actually the ones that did scenario analysis.

So if I've got any advice out there is, if you're doing that parameter identifiability, if you are going through that effort, expand that and look at how, how important, figure out which parameters matter for your predictions. It makes justifying choices and those subjective choices so much easier.

I was very nice to see that the objectives were always very clear, clearly articulated in all of those reports. However, which quantity, how that translated in quantities of interest, that was often less, less explicit and I only found two reports where they actually did go qualitative uncertainty analysis in the sense that, that it was in a, in an easy to find spot where they were justifying key assumptions and limitations.

When I was looking at the comments from the IESC itself on those reports, well, the obvious one, especially for those two that didn't have a formal uncertainty analysis was a recommendation to do a formal analysis.

But then, the common themes that came back were make sure all the relevant parameters and boundary conditions are included in the uncertainty analysis and in terms of processes, recurring three themes where there, dealing with the uncertainty and conceptualization of faults or representation of climate change.

In a minute I, very like, pretty much like to have Chris comment on that a little bit as well, ‘cause this was just my interpretation of the IESC advice, see whether Chris has anything to add to that. I'm just going to go to my final slide.

**Interviewer: Luk, could I just maybe get you to just, just pause there ‘cause I think that is a really important question and we've certainly got some time to take some questions.**

**But Chris, could you maybe just expand a little bit on your own experience on behalf of the IESC on advice that you're getting, what are some of those common areas, either in relation to this particular Explanatory Note, I know, it's not necessarily your individual area, or more generally, across all the advice that you, you receive?**

Interviewee 1: Yeah, happy to do so Fiona and I'll ask Peter to come on if I miss something.

But fundamentally, Luk’s little review has nailed the issues that we're constantly looking for and that is just that, that comment that he made in the previous slide about shining the spotlight on the assumptions, we want to know, we want to see the data, we want to see the assumptions, we want to see the parameters, we want to know how the modelling has been approached and if you, as Luk’s rightly summarise, if you go through our advises, these are common themes, we're constantly reiterating that this is what we want to see, this is why we want to see it.

Essentially, we're just trying to understand what the impacts are and we recognize that it's an environment where you have to take it into a risk framework. You can't have all of the information all of the time that you need, so very much in the groundwater modelling space there are a series assumptions that have to go into the modelling and we want to know what those are.

We know you don't have all of the data, all of the drill holes that you might like to have, etc, etc but nonetheless, for us to be able to provide advice to regulators as to whether or not the best job has been done with the limitations that are, that exist, we need to see the information and the data and the parameters and so forth and generally it is, it’s pretty rare for us to see a really well done study. Apologies for those participating who do that work but that's the facts.

Faults are a particular problem, which is why we're doing the, how to deal with faults in these environments, Explanatory Note which is out for, for comment at the moment.

And what we're often missing is that climate change piece. We know the climate is changing, we know things are going to be different going forward and we know that mine sites are long lived production sites. So being able to consider all of those elements is important to our ability to provide advice that will assist the regulator's making decisions as to how to manage this proposed operation. Did I miss anything or is that a reasonable summary?

Interviewee 4: I think it's a reasonable summary, Chris, that the phrase that I will add, which you often use is that every assertion should have a justification, with it but I would like to add the point, that it's not just the projects that come to the IESC, it's, it's for the Office of Water Science, it is projects that we do, that we see in EIS’s that we're asked to provide advice on as well.

It's a fairly common problem with that, and it is really, a lot of it is the, explanation of the assumptions and what the limitations that cause from those assumptions, as I think Luk was talking about with it.

And it doesn't also mean, can I just add, it doesn't also mean that it needs to be a full blown numerical 3D model either. Sometimes just doing a straight analytical model is fine with it, but obviously requires justification why you went there with it. That's, that's all I'd really add, Chris.

**Interviewer: Thanks, Peter. We do have a question here for you, Luk, from one of participants around. Can you elaborate a bit more why the sensitivity, sorry, what the sensitivity index is and any references so I can come to your slides in a minute but would you like to talk a little bit more to the sensitivity analysis Luk?**

Interviewee 3: Yes so in that particular, for that particular graph, the sensitivity index that we used, in its simplest, it's basically a value from zero to one. If it's one, the parameter is very sensitive sorry the prediction is very sensitive to that parameter. Like, if it's zero, it's not important.

The particular technique I used for that is, it's a density based sensitivity analysis developed by Andrea Saltelli. I'm more than happy to give, well, it's part of the Bioregional Assessments methodology, we use it in all of our models there but I'm more than happy to give you the reports in the papers that explain that and it actually is implemented in a Python package called SALib, which is reasonably user friendly, if you know your way around Python.

Interviewee 1: Thanks Luk, can I just add to that, is some information in the Explanatory Note in appendix A4, titled sensitivity analysis, that mentioned Saltelli, got this reference 2002 but there's plenty more available in the press and it mentioned Jacobian, essentially the Jacobian is a common method used with MODFLOW for relative composite sensitivity analysis. So there's some guidance already in the Explanatory Note, and we'd be happy to provide more if you need.

Interviewee 3: So, sorry, I can't help myself but with technical detail there if you go for the Jacobian. So a Jacobian is only a snapshot, it's based on in sequence changing all of the parameters by moving them up or down one at a time, especially for models that are nonlinear or complex, that can be an underestimate of the sensitivity and you can actually get it, get it wrong, very intuitive example would be a drainage conductance.

If your drainage conductance, if that conductance is higher than your surrounding hydraulic conductivity, it’s not going to have an effect on an outflow. If your conductance is lower than the conductivity, it will have a very big impact, so depending on where that value is, the sensitivity might be very big or very small.

So I just wanted to point out that don't rely on Jacobian’s alone to calculate sensitivities and if you look at how best works, for instance, it calculates Jacobian every time it gets a new parameter combination, so it is actually implicitly acknowledging that those sensitivities changed through time. Sorry, I needed to get that nerding out of me.

**Interviewer: Thanks Luk, appreciate it.**

Interviewee 1: That's good but it's a great first step and there's plenty more you can do.

**Interviewer: Peter, I'm not sure if you want to elaborate if there are already some areas for this particular Explanatory Note that you are looking to update already that have kind of on the list.**

Interviewee 4: Just from me, not specifically with it, though Luk gave that, which is still on the screen, that nice little summary of what he's reviewed in there, but it is, the concept is for the Information Guidelines that they are updated every three years and as part of that, we would be looking at doing similar for the Explanatory Notes as appropriate.

So we, we have it on our agenda, what that will look like moving forward as part of that review. No, we haven't had that discussion with the committee yet.

**Interviewer: Okay, so this is a good opportunity if you do have some thoughts on that. Luk, what I'd like to invite you while some people think of some other, oh, here we go. Hugh, there's a question here around what was the guidance on climate change you mentioned again, so it was at the DELWP guidelines?**

Interviewee 2: Yes, it’s DELWP in Victoria. Sorry, I'll just do a search for it and put a link in the chat.

**Interviewer: You can chuck that in the chatroom, that would be obviously appreciated by them.**

Interviewee 2: Yeah, I’ll do that.

**Interviewer: Oh Peter’s already done it.**

Interviewee 2: Yeah, I just done it Hugh. Sorry.

**Interviewer:** Luk, we talked about these last two slides of yours just in terms of some of these references just while we're on that.

Interviewee 3: Yes. The final slide, that's really it.

This is what, when I'm building a groundwater model and doing uncertainty analysis, these are the things I'm looking for when I'm reviewing groundwater modelling uncertainty analysis, these are the things I'm, I’m looking for.

So that fatal flaws checklist to me, it boils down to those three questions. It's figuring out at first, what matters to the various parties involved, what matters to the prediction, and that second one that'll guide me through everything I do in model, in model developments.

Everything I do, will, I will look through that lens and it's only then that I'll look at what is the available data, tell me about the prediction, what can I constrain.

So that's, the following slide is just a slide with references so for those who have afterwards, want to go through a couple of that detail and look at the things that we mentioned, here, all we kind of, the things we cited in the presentation.

But if, we’ll do open it up a bit, that fate I, I'm very keen to have feedback on that fatal flaw checklists, so we wrote that about two years ago now, three years almost. I'm very keen to see or to hear from consultants, how does it work in practices, is it useful checklist or not, is it very, is it difficult, is it hard to use, is there any suggested improvements in that fatal flaws checklist.

**Interviewer: Thanks Luk. We've also got another question here. Can the panel, expand on the comment about documenting the model workflow, we'd like to make an initial response on that one.**

Interviewee 1: I need to, I need some more information about that document, the model workflow, I don't think we want a document, the model workflow any more than we've put it, any more than we presented it. It's just meant to be a framework to indicate roughly how the workflow might go.

As we said, it's not a guideline, it's not a step-by-step recipe. If we were to go much further, it would become something like that and then you start to have to pick winners amongst the various techniques. So if that's where you're going with it, I'd be, I'd be against documenting it. Should, should consultants document that workflow? Yeah, maybe if it helps tell the story. Luk, do you have a view?

Interviewee 3: I think I was reading this question about how to document and what like a groundwater modelling workflow that you've built like a specific model workflow.

**Interviewer: How did that person who asked that question, just to let me know in the chatroom, and I'm, I’m happy to let you guys --**

Interviewee 3: So what I’m, so what I mean with documenting a workflow of a groundwater model in uncertainty analysis. If you're building a groundwater modelling a GUI, there's a lot of data sources that you need to pull in. You need to have your geological model, you're pumping data and it often requires a lot of pre and post processing in Excel or GIS software to pull all that data together and put that in your groundwater model.

And if you then get into the actual calibration and uncertainty analysis, again, there's a lot of these things, these actions that you just do in your GUI. What I mean with documenting and automating that workflow, what we've tried to do increasingly now is capture all of those steps automatically in a script.

One of the reasons why one went that route is if you want to do uncertainty analysis, you need to be able to automatically change parameters, that means coding that up so you need a script to do that but it has saved me a numerous times when I'm writing a report, and I'm asked to look at a number, or a choice that I made six months ago. I can actually go back to that script and see, this is how I took in that source information about pumping rates. This is how I did the processing, the pre-processing and this is how I translated that into the well package for MODFLOW.

I've got that documented, documentation there and I can reproduce it. If you want to have examples of that, the GMDSI website has a couple of examples of how you can actually capture the entire workflow of a groundwater model and uncertainty analysis and if you go to the website of the Bioregional Assessments, if you dig around there, all of the models that we've, we've done are built like that, they have a Python script next to it and if you download the groundwater models, you can actually run that model again, and go through all of the steps of taking the input data, generating the models to then taking the model output data and generating the pictures and the graphs that we used in the model reports. So all of that is automated and captured. Hoping that answers your question.

Interviewee 3: Just a, just a little bit more info. Thanks, Luk. That does clarify things for me. Anyway, in my job as a reviewer, I, I'm seeing more and more reports, put a model workflow flowchart in on how they did the modelling and that's sometimes helpful to understand what they did. So I think if you, if it helps with communication and it goes in the report then I have to, I support that.

**Interviewer: Thank you for that. All right, before, just please keep bringing your questions through, we've got some time for more questions. Just while you're doing that, I'll just go back to those references that you've added in there Luk. Are these the same references available in the Explanatory Notes or are there some new ones there that perhaps aren't in the Explanatory Notes?**

Interviewee 3: I believe the only new ones are the, the first, the first new one so the DELWP. In fact -- and the, the paper, the groundwater paper by John Doherty and Cath, Cath Moore.

**Interviewer: Okay.**

Interviewee 3: Basically, anything that’s published after the Explanatory Notes. And Hugh, you might want to expand on the, the Moan and Vink --

Interviewee 2: Yeah, Look, I, we talked about a little bit about causal pathways for impacts and this, you know, this is, this is not new stuff, there was a National Water Commission report done in 2010, by Moran and others and Robinson and others, Paul Howe as well on, on mining impact assessment, in fact it was cumulative mining impact assessment and that just once again, reiterated the, the source pathway receptor model so the source of the source of the impacts of mining development, the pathways, the causal pathway for impact and the receptor in the environment is the thing that you do the assessment against.

You know, that's, it's not, it's not rocket science, it's not new and the causal pathways that we talked about in the Explanatory Note essentially just fit into that. So this is the way you know, this is the best practice method that the mining industry has adopted the Minerals Council of Australia support that source pathway receptor model.

So the Explanatory Note uncertainty analysis just works with that and we're also pains to, we didn't really emphasize it enough I think in this talk, the GMDSI initiative, that second last reference down there. Bringing, bringing out some, some very good methods and techniques, and really urge people to go there and look at the webinars as well, they're quite good.

And yeah, apologies for not putting the link to the DELWP guideline at the top.

**Interviewer: Thanks Hugh. So while people again, still got time for questions, and will, if you're interested to get a copy of the slides, please just email the IESC secretariat so Ben I might get invite you to put both the IESC website address into the chatroom as well as the email address, if that's okay.**

**While, we're just inviting other people to ask the most questions. I just want to bring to your attention, there are still two more masterclasses in this series so we've got assessing groundwater dependent ecosystems, this time next Wednesday and then the Wednesday after that is the third one deriving site specific guideline values of physico-chemical parameters and toxicants. So again, just email the IESC secretariat if you'd like the registration details for those two masterclasses.**

**Okay, just while, we're just looking for more questions here, Thanks, Ben.**

**I'm just going to ask you all a few more questions just by another snap poll and then I'm going to just open up everyone to join in an open discussion.**

**So there's just three questions that should be on your screen now. Just gives us a little bit of immediate feedback but we are really interested particularly as a group of consultants for your feedback on these Explanatory Notes including that fourth one that's being developed on faults.**

**So if you're starting to think about some questions there, we will be also providing an opportunity via survey to get some more information but if you've got any other thoughts just some feedback on this, or other areas you might have been interested in, happy for you to put that into the chatroom. If I could just get you to respond to those polls.**

**While you think about the questions for the panel, this is a pretty unique opportunity to have both the co-authors, IESC and DAWE in the one session so I encourage you to make the most of that.**

**Luk and Hugh, I’ll invite you to see if there's any other areas you might like to expand on as well, once we go to the open chat but I'm going to close the poll.**

**Okay, I'm just going to share the results from that poll. Now we all know that technology is always somewhat limiting but what we've got is generally people have thought this, met they, the purpose, which is really just to provide an introductory and background and just touched on a couple of the key points in the Explanatory Note.**

**But looks like the technologies works pretty well today. It's not ideal. Obviously, we'd love to do this in a face-to-face environment and it looks like everyone's happy to share the, the idea of doing these masterclasses with their colleagues so that gives us an immediate feedback at this point in time.**

**What I'm going to do now is just stop those results as well as the presentation and because we wanted to also provide a bit of opportunity just to share some other dialogue and experiences. What I'm going to just do now is invite everyone, if you're happy so I guess that's the formal end to the webinar unless there's any last minute questions coming through. So people who have other things to go on to that's fine, this is the, the end of the webinar.**

END OF TRANSCRIPT