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<tr><th>Ref</th><th>Subject</th><th>Issue</th><th>Response</th></tr>
<tr><td>1.</td><td>Tunnel Construction</td><td>Tunnel construction – do tunnel boring machines exist which meet the specifications given Page M1-13.
Can the TBM manage all the foreseeable ground conditions (including possible igneous intrusions, large boulders etc) over the 4.9km length, what compromises need to made and what are the associated risks, - examples of successful TBM's on other projects in similar ground conditions would assist.</td><td>Yes. A mixed shield slurry type TBM has been chosen as being the most versatile TBM type presently available to cope with the expected ground conditions. These are ranging from gravel, medium and fine sand as well as rock of considerable strength (up to > 250 MPa).

Bidders for tunnelling contract currently being evaluated have confirmed the suitability of Slurry TBM use for the Corrib project.

The tools of the TBM cutter head used to excavate the soil or break the rock are fitted to the cutter head by bolted connections. This allows regular inspection and replacement (if required) by means of compressed air work, a task that is commonly executed for long distance tunneling projects. This way it is ensured, that mining and rock cutting will be equally efficient over the complete length of the tunnel.

Projects that have been completed with a slurry type TBM include:

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<tr><th>Country</th><th>Project</th><th>Length</th><th>Diameter</th><th>Geology</th></tr>
<tr><td>Germany</td><td>Sewer tunnel Berlin</td><td>1,800 m</td><td>3.770 m</td><td>Sand, Stone, Marl</td></tr>
<tr><td></td><td>Europipe tunnel</td><td>2,535 m</td><td>3.820 m</td><td>Clay, Marl, Sand</td></tr>
<tr><td></td><td>Han River</td><td>1,287 m</td><td>3.800 m</td><td>Rock, Gravel</td></tr>
<tr><td>Korea</td><td>Cable tunnel Seoul</td><td>800 m</td><td>3.060 m</td><td>Rock, ground water</td></tr>
<tr><td>China</td><td>Pearl River</td><td>1,500 m</td><td>3.780 m</td><td>Weathered rock, Loam, Sand, Gravel</td></tr>
<tr><td></td><td>East-West-Pipeline</td><td>1,720 m</td><td>3.180 m</td><td>Weathered Rock, Quarzite, Ground water</td></tr>
<tr><td>NL/Ger</td><td>Emstunnel</td><td>4,015 m</td><td>3.000 m</td><td>Clay, Sand, Gravel, Peat</td></tr>
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<tr><td>2</td><td>Tunnel Construction</td><td>Can the cone crusher mange the range of rock strengths that can be foreseen? - range of rock strengths and capabilities of crusher would assist</td><td>Yes. The TBM will be equipped with tools to effectively excavate lose soil and cut rock and boulders. Only those boulders or stones that are cut small enough to pass through the openings in the cutter head will be further diminished in size by the rock crusher. Due to the abrasivity of the soil it is envisaged that also the cutting tools of the crusher will require maintenance and/or replacement. For this purpose a jaw crusher will be used on the TBM instead of a cone crusher. The jaw crusher is located in a separate chamber behind the cutter head, which can be closed to allow safe access under compressed air without the need for a full face compressed air intervention.</td></tr>
<tr><td>3</td><td>Tunnel Construction</td><td>What 'exceptional circumstances' will halt the TBM and how are Shell planning to investigate that these have a very low risk of being present.</td><td>Based on the information of the geotechnical and geophysical investigations to date there is no evidence of any circumstances that would lead to a complete stop of the tunnelling works.

Theoretically the following scenarios could result in a complete stop of the works, in case it should not be possible to resolve them from inside the TBM or by means of compressed air work at the face of the TBM:</td></tr>
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			- Soft peat layers of significant thickness. These layers would not provide sufficient bearing capacity for the weight of the TBM. However, there has not been any evidence, that such layer will be encountered at the depth of the tunnel alignment. In addition, calculations have shown that the weight of the TBM is not significantly higher than the soil that will be excavated along the alignment. This means that there will be no significant net vertical downward loading on the peat layers. In addition the peat layers have already been consolidated due to the load of the current overburden. As such there will be no excessive settlement of the TBM. - Large man made (steel) obstacles or large tree logs that could not be handled from inside the TBM. As stated above, information of the geotechnical and geophysical investigations to date geophysical show no evidence of any such obstacles.
4	Tunnel Construction	Are there any risks of 'blow out' of the bentonite from the tunnel face or grout from the annulus onto the estuary bed - how will the pressures be designed and monitored - what impact could this have on the estuary - is there a requirement for monitoring the estuary bed.	In order to prevent a break-out of circulating bentonite slurry or excessive settlements at the surface the pressure and flow of the bentonite slurry is controlled at the soil face in front of the TBM. For this purpose, a slurry type TBM will be deployed, allowing an individual adjustment of slurry flow rate and pressure. The pressure of the slurry at the soil face will be controlled by a compressed air cushion inside the TBM, which allows for rapid changes of the slurry volume in mixed ground conditions, while automatically maintaining a pre-set face support pressure (slide). The pressure at the soil face will be continuously measured, monitored and alarmed when limit values are met. The maximum allowable and minimal required slurry pressures have been calculated at critical locations. For the tunnelling operation, detailed slurry pressure calculations will be carried out for any position along the alignment. The slurry volume inside the working chamber of the TBM will be continuously monitored and the flow will be shut down automatically in case a low or high level alarm is triggered. In addition to monitoring the slurry pressures, feed and return lines of the slurry system will be equipped with flow meters, continuously measuring the flow of slurry to and from the excavation chamber. Thus, in the unlikely event of a slurry break-out due to unforeseen ground conditions, only a limited amount of slurry suspension may be lost before the system is shut down and mitigation measures can be deployed. The injection of grout to the tunnel annulus is controlled in a similar manner as the slurry flow. The risk of a grout breakout however, is substantially less than that of slurry, since on the one hand a much smaller amount of grout is available at the TBM (approx. 2 m3 at any time). Also, it is very unlikely that the grout would break out to the surface, since it will follow the path of least resistance along the TBM outside to the front of the TBM, where it will enter the slurry system and be fed back to the separation plant. Since the cutter head is slightly larger in diameter than the TBM shield diameter, there will be a small bentonite slurry filled annulus between the front of the TBM and the rear tail skin at which the grout is injected. If the grout was injected at a pressure significantly higher than the slurry pressure, it would not break through the soil, but find

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			its way along the TBM to the front.
5	Tunnel Construction	The final mitigation in case of an obstruction to tunnelling is intervention from the surface with a sheet piled pit with coffer dam page M1-13 – has the impact of this been assessed?	Yes, see Chapters 5, 12, 13 and 14 of the Onshore Pipeline EIS and associated technical reports (Appendix)
6	Tunnel Construction	Tunnel construction – demonstrate knowledge of ground conditions is adequate so that tunnel can be constructed without any remedial action from the surface. Normally prefer to construct tunnel through uniform layer – could be problems at surface of bedrock or if igneous inclusions encountered. Page M1-13	The geotechnical and geophysical information available at the time of application was considered sufficient to assess the feasibility of the tunnel construction. The tunnel boring machine (TBM) has been specified for the construction tenders – choosing the most versatile TBM type presently available for this type of geology. The most significant risks to a tunnelling project of this type that would require a surface intervention have been outlined in Item 3 above and there is no evidence contained in the ground investigation data that would indicate the presence of such a situation. Further detailed geotechnical investigations are underway and ongoing review of this data confirms the original ground investigation data. The tunnel alignment under the bay is essentially within superficial sediments that are typical of estuarine deposits, and which comprise a relatively consistent material comprising dominantly sand and gravel. The presence of igneous intrusions within the bedrock is therefore not considered an issue for the tunnel alignment under the bay (see below for further discussion). Notwithstanding this, the TBM will be equipped to mine through the rock expected in the bay area. Based on geotechnical review of Sruwaddacon Bay, boulders where present are more likely to be encountered at the interface of the bedrock and superficial sediments. Where there is a significant cluster of boulders present (though this not evident from the ongoing investigations) then this may affect the progress rate of the tunnelling works, but as described above the TBM will be equipped to mine rock and boulders of the type to be expected within the bay. The presence of possible igneous intrusions was indicated by the geophysical survey within the bedrock under the bay. These intrusions within the bedrock under the bay will not be encountered by the tunnel as the tunnel will be located within the bay sediments. At either end of the tunnel alignment the tunnel over short lengths is within rock (App M1A, drawings 401 to 404). Whilst igneous intrusions within the rock sections of tunnel cannot be discounted the effect on the works would not be considered significant given the short length of intrusions and the fact that the TBM will be equipped to mine through such rock. The ongoing detailed geotechnical site investigation campaign is being conducted to verify the information that has been obtained by the earlier geotechnical and geophysical investigations. The ongoing investigation comprises further intrusive techniques which includes rotary and percussive boring and cone penetration testing.

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			The ongoing investigations will also provide a verification of the interface between bedrock and sediments. Where the TBM will leave/enter the bedrock the investigations spacings are have been decreased in order to optimize the tunnel alignment at the interface of bedrock/ sediments (within the corridor specified in the application). It is not uncommon to select an alignment that does not follow a uniform layer. For the tunnel alignment decisions have been made to align the tunnel within the sediments for the majority of the tunnel length in order to minimize the overall impact of the project by reducing the execution time to a minimum. These sediments comprise a relatively consistent material that comprises dominantly sand and gravel. A deeper alignment within bedrock over a larger distance would significantly affect the project duration and additionally require more frequent cutting tool changes under compressed air and at higher pressures. The risks associated with these tasks are therefore also minimized by the choice of shallower alignment.
7	Tunnel Construction	Vibration M1-15 the tunnel boring will be a continuous operation whereas traffic vibration will be intermittent is there any significance in the duration of a vibration rather than its intensity with respect to ground stability?	Assessment of vibration affects on ground instability, particularly on Dooncarton Mountain, would take into account the greatest magnitude of vibration (measured in ppv or g) at the site of sensitive slopes irrespective of the duration of the vibration event. In this regard, the duration of the vibration would not be considered significant. Ground vibration produce by road traffic are unlikely to cause perceptible structural vibrations in propertied located near well maintained and smooth road surfaces. As such, road traffic vibrations can be largely minimised by maintenance of the road surface (EIS vol 1 9.2.3.2). Baseline vibration readings taken at roadside locations were in the range 0.175 to 0.275 mm/s (EIS vol 1 9.3.1.3). Notwithstanding the above, with respect to the vibration affect from tunnel works on the surrounding slopes: (1) The calculated vibration (in peak particle velocity, ppv) induced by tunnelling at a house 240m distance from the tunnel has been determined as 0.02mm/s (EIS, vol 1, 9.4.4). The more sensitive steeper upper parts of the Dooncarton mountain slopes where previous failures are located are some 800m distance from the tunnel. (The nearest main road is about 350m distance from the sensitive steeper upper slopes of Dooncarton mountain) (2) At a distance of 800m, the ppv would be notably less than 0.02mm/s, which would not be considered significant. For comparison purposes, a door slamming within a room with a wooden floor would generate a ppv of about 2mm/s. (3) The primary mechanism of slope failure on the previously failed slopes was essentially water pressure related – which is distinct from vibration induced failure. The failures were not as result of vibration.

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			(4) Typically the safe limit for vibrations on slopes is in the ppv range 15 to 25mm/s. Groundborne vibrations arising from the operation of the TBM and from construction traffic (either separately or in combination) have been predicted and are outlined in Chapter 9 of the EIS and associated appendices. The magnitude of the predicted vibration levels in combination with the distance of the road and the tunnel trajectory from the slopes of Dooncarton are such that the probability of vibration affecting ground stability can be ruled out.
	Tunnel Construction	Vol 2 Book 5 M4 Employees will be familiar with tunnelling in similar conditions – where will such staff be recruited and how does it mitigate the risks?	Yes this is assured through tender prequalification procedures which have confirmed that potential contractors have the necessary experienced staff.
8	Debris Channel Crossing	How far has the design of concrete slabs progressed to protect the pipeline from impact and erosion where it crosses the debris channels. What is the process for determining horizontal spread of the slabs and has the need for vertical support / "toe" walls both up and downstream to protect against scour under the slabs. M2 page vii M" page 178 refers to JPK drwg	Photographs of channel 2 has been provided. Channel 2 is essentially a field drain boundary comprising an upstanding bund and drainage ditch. The ditch is about 1m wide and infilled with natural vegetation. Depth of channel is estimated at less than 1m. Based on the size and condition of the channel it appears unlikely that there was any significant erosion and incision of the channel bed or passage of debris along the channel during the 2003 landslide event. The topography is also relatively flat at the location where the channel crosses the pipeline. The mitigation measures to protect the pipeline from potential scour are shown on drawing DG0702 P03. This includes: • Pipe burial at 1.6m below true cleaned bottom of ditch. Therefore any infill and scour/incision from previous runoff/debris flow is taken into account. • Placement of reinforced concrete slab 500mm above pipe. • Concrete slab extends 1m beyond edge of pipe trench. Allowing for 45 degree side slope on pipe trench with slab at (say) 1150mm from base of trench then the slab would extend a minimum of 2.15m beyond pipeline/service pipes. This is the extent of the channel upstream/downstream scour protection. • Concrete slab extends 1m beyond edge of drainage channel. The protection provided at the channel crossing of the pipeline, which comprises a reinforced concrete slab (drawing DG0702 P03), is buried at a depth measured below the cleaned bottom of the channel; during excavation works should it be shown that the channel bed has been eroded/incised then the protection (and pipeline) will be buried at a correspondingly deeper depth. Given the location, size and condition of the channel and the fact that the channel shows no signs of previous erosion/incision it is considered that the channel does not present a channelised debris flow risk to the pipeline taking into account the proposed protection

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			measures. Further protection/mitigation measures are not proposed.
13	QRA	Q6.4 Section 6.4 identifies land slide debris risk but has not included it in discussion analysis. Given additional design measures proposed would expect a justification of those protection measures .	See answer to Q8 above.
16	Tunnel Construction	The drawings and text indicate that launch and reception shafts will be formed using sheet piled cofferdams. The drawings indicate that the piles extend into rock. No explanation is given as to how the piles will be installed in the rock and what the risks to the structures are if the piles cannot be taken to their design depth.	HOLD
	Tunnel Construction	Piling of access chambers(launch and reception shafts) will also create noise and vibration. Has this been assessed? Note that sheet piles may not penetrate bedrock unless it is excavated – bored or secant piles may be required	HOLD