[Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	4, 5, 6 (Select the number from “Areas of Technologies Requested”)
Title	Evidence Support Logic and BowTie tools for supporting and communicating decisions about technology deployment and risk mitigation approaches in the face of uncertainty
Submitted by	Quintessa Ltd

1. Overview of Technologies (features, specification, functions, owners, etc.)

The integrated use of Evidence Support Logic (ESL) and BowTie tools is an innovative way of informing and communicating decisions and the logic upon which they are based, leading to efficient planning to ensure effective technology deployment and risk mitigation.

To create a hydraulic barrier, TEPCO plans to freeze the ground up gradient of the o.p. 10 m area at Fukushima. The effectiveness of this remediation approach will depend upon many inter-related factors, about which understanding is to some degree uncertain. Optimized installation and operation of the barrier within the natural environment will require the variability in environmental and engineered characteristics to be identified, assessed and managed. Furthermore, before implementing this hydraulic barrier, plans must be made to mitigate any consequences should the barrier behave unexpectedly (e.g. if the effects on groundwater flow are unpredicted, or if future natural phenomena such as earthquakes or typhoons impact upon the barrier). A complete ‘map’ of the complex interactions and uncertainties that apply (e.g. associated with coupled chemistry-groundwater flow-transport processes), will be an important basis for selecting and implementing a successful and optimized development and mitigation strategy.

It can be difficult to identify, understand and assess the implications of uncertainty associated with natural variability, information gaps, and expert judgements on key issues. However the technique of ESL has been specifically developed to support decisions that are subject to variability and uncertainty. ESL was originally developed by Bristol University in the UK, and has since been adapted and implemented in the TESLA software tool. It has been applied successfully for high-profile decisions in the nuclear, carbon capture and storage, and oil and gas industries. This includes a range of applications in the UK and Japan for nuclear decommissioning and waste management projects. An example application was in one of the UK’s highest profile and highest risk decommissioning projects, supporting the assessment of

mitigation options for leaking historic tanks and silos containing high hazard sludge wastes.

ESL uses a 'decision-tree' technique common to many decision-supporting approaches but with the key difference that judgements on *evidence for* and *evidence against* supporting judgements are explicitly and independently recognised. In the 'Italian Flag' representation (green = evidence for, red = evidence against), what is left (white space) is residual *uncertainty*. ESL uses logic and 'Interval Probability Theory' to propagate confidence in/against judgements, and thus uncertainty, through the tree to provide an assessment of confidence in the overall judgement (Figure 1).

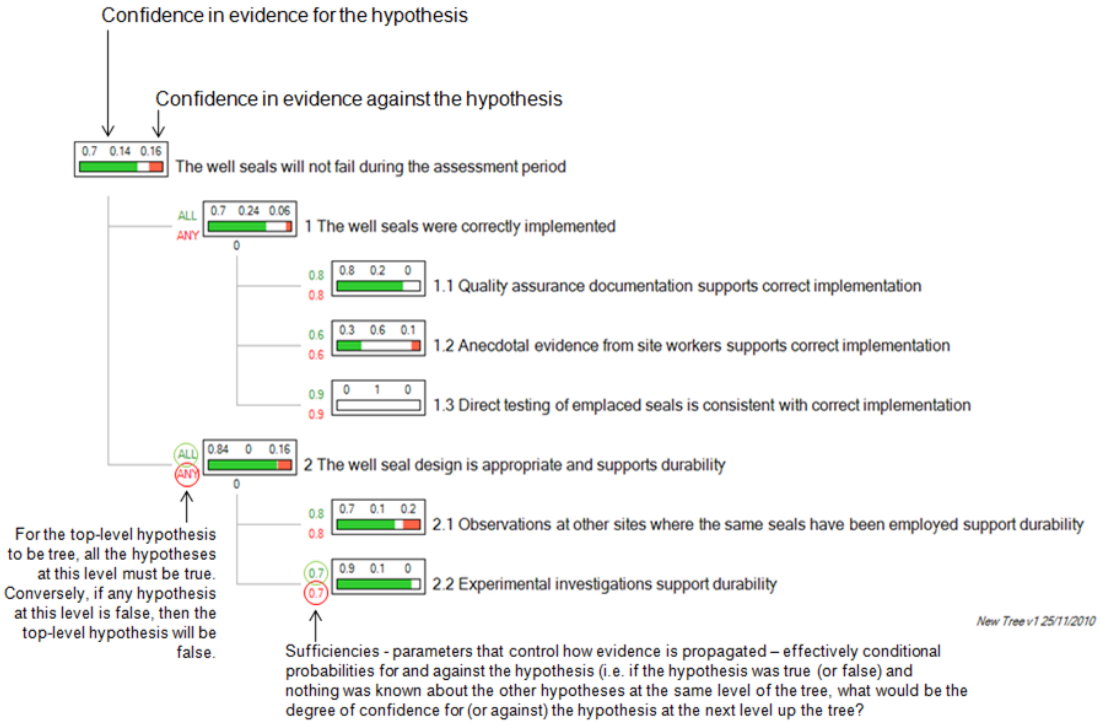

Figure 1: Example hypothesis model illustrating how degrees of confidence in hypotheses that closely relate to information or data (at the extreme right) are propagated to determine the degree of confidence in some hypothesis of interest (at top left). An actual tree would typically be considerably larger than this example.

The tree allows a very complex decision to be represented very succinctly. TESLA allows the sensitivity of the tree outcomes to be analysed, and the full audit trail (including documents, links to web pages etc) to be recorded, just a click away. As the audit trail and tree development is time-dependent, the tree can be used as a 'live' tool to continually assess and direct projects.

ESL can be complemented by the BowTie risk management tool. This tool does not explicitly show uncertainty like ESL does, but it is a useful presentational companion to ESL. It helps

identify and communicate key threats, consequences and mitigations associated with risk assessments for project implementation (Figure 2). ESL can be used to justify the choices of elements of a BowTie (threats, consequences top event, barriers etc).

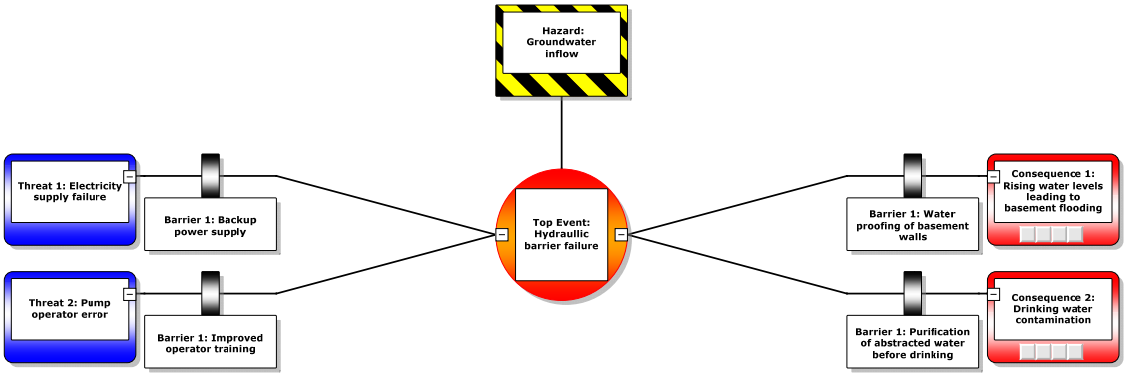

Figure 2: A simple BowTie showing a "top event" at the centre (hydraulic barrier failure) that could cause realization of a hazard (groundwater inflow). Blue boxes represent threats that could cause the top event. Red boxes show possible consequences of the top event. Boxes between the threats and the top event, and between the top event and the consequences show 'barriers', respectively aiming to prevent the top event and the consequences, should the top event occur. An actual bowtie would probably show many more threats, consequences and barriers.

BowTie is an internationally recognised approach that is widely used for risk assessment in several industries, including the nuclear and oil and gas industries. The step-change in benefit here relates to the innovative use of BowTie to supplement the ESL analysis to ensure planning addresses and is informed by characterization of uncertainties and their implications.

Use of ESL, supported by BowTie, would provide a low-cost, but high-value tool to assess and enhance confidence in ground freezing approach and implementation decisions that are unavoidably influenced by various kinds of uncertainty.

2. Notes (Please provide following information if possible.)

- Technology readiness level (including cases of application, not limited to nuclear industry, time line for application)

ESL and BowTie are available immediately. ESL has been applied for a range of different clients, for example JAEA and NUMO in Japan, DoE/CH2MHill for the USA Hanford Tank Farm, NDA/Sellafield Ltd for UK Legacy Ponds and Silos, Royal Dutch Shell for carbon capture and storage portfolio decisions, underground gas storage and cavern stability projects, and various

international Carbon Capture and Storage projects. BowTie has been applied for a further range of clients and industries, in particular in the oil and gas industries.

- Challenges

The quality of an ESL model reflects the quality of the data input and associated judgements. However, even an ESL model with sparse input can be a very useful prioritization tool, showing the uncertainties that are most likely to enhance overall understanding if investigated.

- Others (referential information on patent if any)

TESLA is Quintessa Limited's Intellectual Property (IP). Licenses are available. The BowTie code is owned and licensed by Governors B.V. (Netherlands), supported also by RiskTec Ltd.
http://www.quintessa.org/software/TESLA/index.html

【Areas of Technologies Requested】

(1) Accumulation of contaminated water (Storage Tanks, etc.)
(2) Treatment of contaminated water (Tritium, etc.)
(3) Removal of radioactive materials from the seawater in the harbor
(4) Management of contaminated water inside the buildings
(5) Management measures to block groundwater from flowing into the site
(6) Understanding the groundwater flow