DEVELOPMENT OF AN ENVIRONMENTAL RESPONSE HANDBOOK FOR BNFL SITES

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ABSTRACT

The BNFL Group of Companies owns and operates a number of nuclear licensed sites in the UK, Europe, and US. These cover fuel manufacture and reactor services; power reactors; spent fuel management; and nuclear decommissioning and clean up.

To implement its environmental policy, BNFL needs to have tools and techniques that allow it to:

a) Respond appropriately to Environmental Trigger Events (ETEs), and to
b) Provide assurance that BNFL is able to manage contaminated land in the short to medium term (prior to site closure).

As a consequence, over the past five years, BNFL has developed the Environmental Response Handbook (ERH).

ETEs on a nuclear licensed site cover a number of scenarios:

- Proactive action to remediate known contamination;
- Change in behavior or location of known contamination (e.g. mobility increase);
- Revision of permitted environmental limits on contaminants;
- Other changes in regulatory regime;
- Precedent set by a third party; and
- Discovery of previously unknown contamination or new contaminating event.

The main themes of the ERH are:

- Global considerations for remediation on an operational site;
- Detailed consideration of the application of remediation to the current ETE(s);
- A maintained 'toolkit' of favored remediation techniques; and
- Case studies and action plans

In this paper the process undertaken to develop the ERH is discussed. Details of the structure and application of the ERH are also presented.

INTRODUCTION

The BNFL Group of Companies owns and operates a number of nuclear licensed sites in the UK and US. These cover fuel manufacture and reactor services; power reactors; spent fuel management; and nuclear decommissioning and clean up. The main UK site -Sellafield - is located in Cumbria, and has had a history of power reactor operation (Calder Hall) and spent fuel management operations.

BNFL has a legacy of radioactively contaminated land, mainly resulting from incidents that occurred in the 1950's and 1960's (before BNFL's formation in 1971). Construction of buildings more recently have had environmental protection features incorporated into their design and operation, and BNFL has an ongoing program of retrieval and conditioning of historic waste arisings.

The legacy of ground contamination requires management in the period between the present day and the potential remediation options associated with site termination and clean up. This demonstrates proactive control of both the ongoing intrinsic remediation and also highlights intervention if and/or when necessary.

BACKGROUND

An internal BNFL review of historic waste liabilities provision resulted in the formation of the Sellafield Site Management Project (SSMP), a 5-year program designed to determine the Best Practicable Environmental Option for contaminated land post site closure. In parallel with this long-term goal, it was recognized that BNFL would need to have tools and techniques, which allowed it to:

a) Respond appropriately to Environmental Trigger Events (ETEs); and to
b) Provide assurance that BNFL is able to manage contaminated land in the short to medium term (prior to site closure).

Because this would result in a proactive (rather than reactive) environmental policy, the Environmental Trigger Events on a nuclear licensed site were specified in more detail. The ETEs cover a number of scenarios:

1) Proactive action to remediate known contamination;
2) Change in behavior or location of known contamination (e.g. mobility increase);
3) Revision of permitted environmental limits on contaminants;
4) Other changes in regulatory regime;
5) Precedent set by a third party; and
6) Discovery of previously unknown contamination or new contaminating event.

INITIAL DEVELOPMENT

ETE and Technique Selection

Initial development commenced in 1996. The ETEs considered at this stage were (#2) change in behavior of known contamination; and (#6) discovery of unknown contamination or new contaminating event. The reason for selecting these two ETEs only was that the others were outside the scope of the (then) SSMP study – (#1) being a proactive policy decision, and (#3-#5) being the result of Regulatory or third party action.

Selection of the ETEs (#2) and (#6) limited the scope of the environmental response to that of contingency action. The Handbook at this stage was thus referred to as the Contingency Plan Handbook (CPH).

The optimal structure of the CPH was determined to be prescriptive, in the form of:

"If situation ZYX occurs in location TUW use technique NOQ"
"If situation XYZ occurs in location FGH use technique ABC", etc, etc.

The development of the CPH commenced with a specification of the techniques available for the remediation of sites contaminated with radionuclides, heavy metals, organics or mixed contamination. These were identified from internal company knowledge databases, non-nuclear industry practice, and Internet searches (both direct and via specialist remediation technology databases).

The initial trawl of techniques was then further refined by consideration of their effectiveness in treating known or potential contaminants of the Sellafield site; this included consideration of treatment of mixed organic/heavy metal/radionuclide contamination. The final listing of techniques was then labeled the 'Starting Toolkit'

The next determination was the specification of the potential ETEs resulting from the combination of

- Situation — new event, existing contamination
- Location — near buildings/remote shallow/deep
- Extent — 'hot spot'/spread out
- Response — shield/contain/remove

This work created a Decision Tree that reduced the potential ETE to a series of either/or decisions. Each terminal branch effectively specified the remediation requirements for that combination of circumstances.

Potential techniques identified in the Starting Toolkit were then assessed in a series of workshops against the identified combinations of situation / location / extent / response, and candidate techniques identified for each combination. A multi-attribute decision analysis (MADA) was then used to identify the front runner technique for each combination.

The result of this work was to create a CPH Decision Tree, linking the perceived ETE problem with the front runner solution for that problem. A sample section of the decision tree is reproduced in Figure 1.

CPH Handbook Structure

Underpinning the Decision Tree were a number of supporting documents including a description of the remediation technique in a standardized format, and current costs quoted by technology vendors – usually for the non-nuclear equivalent. These were supplemented by an outline of the strategy to be employed (effectively Instructions for Use).

The 1997-issue prototype CPH thus consisted of the following documents:

- Outline Strategy (Instructions for Use)
- Decision Tree (Technique Selection)
- Technique Description
- Vendor Costs

Operation of the CPH would therefore consist of matching the ETE event with the correct strand of the Decision Tree, reading off the 'correct' remediation method, then applying the result in the most cost-effective manner.

This resulted in a 'one size fits all' approach, as there was very limited scope for specification of alternative technologies. It also presupposed a significant knowledge of remediation (or access to a group within BNFL with such knowledge) to be able to select the correct technology to apply the selected technique.

(As an example. The technique of 'cut-off wall' could be achieved by a number of technologies. These include sheet pile wall, diaphragm wall, secant pile wall, jet grouting, displacement wall, etc. In addition, variations in material of construction include iron pile, cement, cement/bentonite, etc. Selection of a 'one size fits all' formulation would not permit inclusion of the alternatives.)

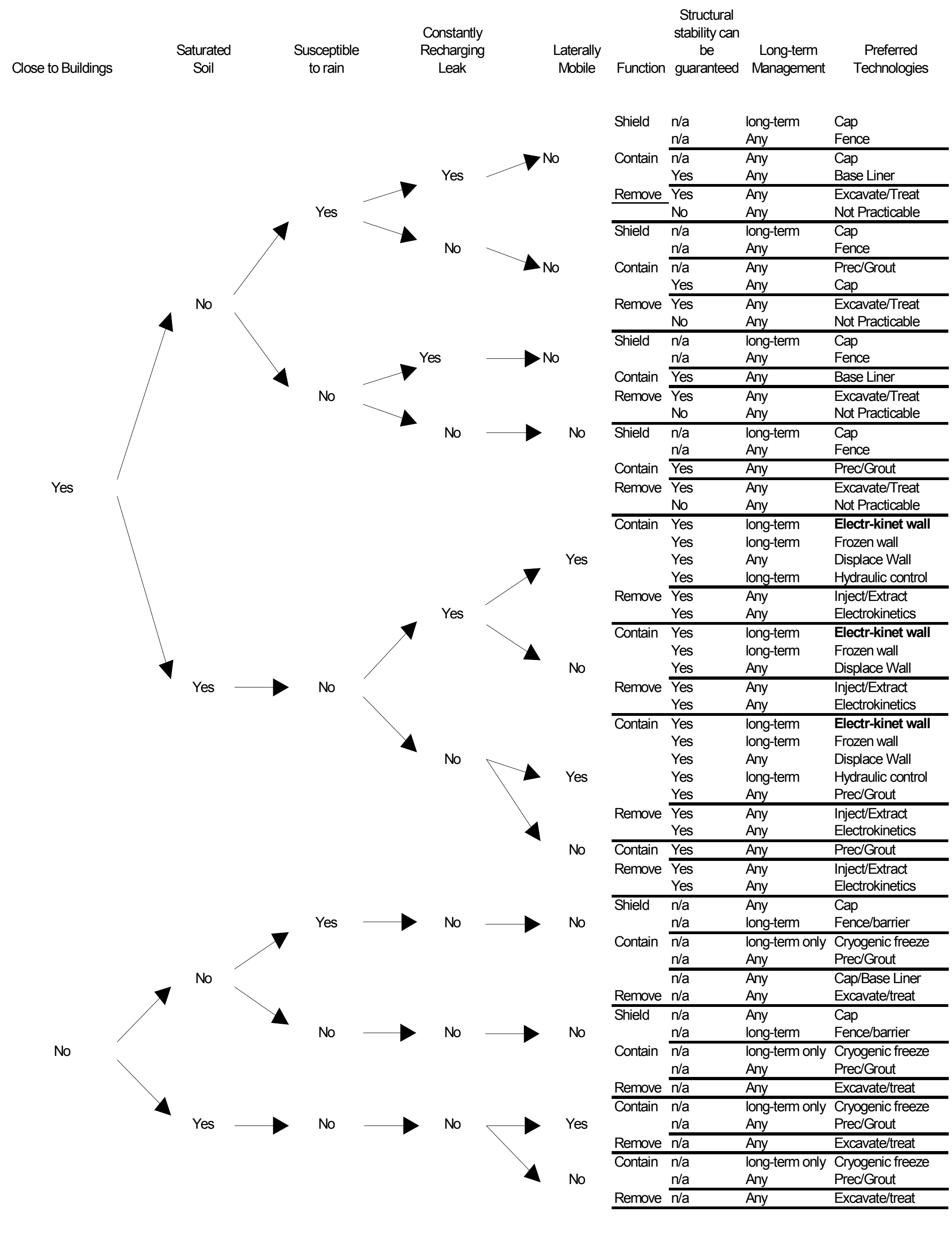

Fig. 1: CPH Decision Tree

HANDBOOK REFINEMENT

As noted in the previous section, development of the prototype CPH indicated the limitations of the prescriptive Decision Tree method. BNFL therefore decided to expand the remit of the CPH to include all of the specified ETEs (#1-#6). As such it was renamed the Environmental Response Handbook (ERH), and included proactive as well as reactive response.

ETE and Technique Selection

The optimal structure of the ERH was determined to be descriptive, in the form of:

"If situation ZYX occurs in location TUW follow the guidance flowsheet for selection of the appropriate remediation technology, action plans and permitting. Undertake selected technique NOP and review during remediation operations and beyond."

"If situation XYZ occurs in location FGH follow the guidance flowsheet for selection of the appropriate remediation technology, action plans and permitting. As risk is ALARA intervention is not justified – monitor and review."

(Comparing the ERH with the CPH equivalent above, use of the guidance flowsheet would indicate a slightly different technique in the first instance (NOP not NOQ), and monitored intrinsic remediation instead of intervention in the second case.)

Refinement of the ERH commenced with a further trawl of available remediation techniques. The Starting Toolkit was expanded to include emerging technologies such as electrokinetics, and also international guidance on remediation technologies [1].

The revised Starting Toolkit was then compared against known and suspected radiological contamination areas (rather than near/far, deep/shallow, etc.), to identify techniques with wide or with limited application. The front runners were once again identified by MADA, and the toolkit subdivided into the 'Main Toolkit', 'Backup Toolkit' and 'Organics Toolkit'. It was recognized that although a technique did not have a wide application, it may still be optimal in specific circumstances. The retention of the Backup Toolkit encouraged greater flexibility by not eliminating techniques with specialized - rather than generalized – application.

ERH Handbook Structure (I)

The handbook retained the modular format for ease of updating, but a number of sections were added in order to convert from the prescriptive CPH format to the descriptive ERH format.

The first of these was the Outline Method Statement (OMS), consisting of a step by step flowcharted guide to the selection of a remediation technique or combination of techniques for the situation/location under consideration. Improvements over the prescriptive method included:

- Assessment of risk factors (radiological, environmental and societal) to determine if the Trigger Event was a real or only an apparent risk. This avoided intervention when the intrinsic remediation case was ALARA.
- Consideration of the logistics of application of remediation techniques on working sites (e.g. no 40' long grout auger drills where the available headroom is less than 20'.)
- Recognition of stakeholder involvement from non-company, non-regulatory stakeholders.
- Inclusion of permitting, logistical planning and post-remediation monitoring.

The second was the Detailed Strategy Document (DSD). This consisted of a series of global considerations and precepts to front end the OMS. The DSD expanded on the outline strategy, and included consideration of the effect of remediation on other parts of the working site. (The aim of the DSD was to retain consideration of the overall picture and prevent too narrow a focus on the task in hand; thus avoiding cleaning up one area at the expense of an alternative location and compounding the overall contamination burden.)

The third was a revamped Technique Description, retitled Detailed Design. This incorporated the three Toolkits (Main, Backup, and Organics), and indicated the function of each grouping relative to the OMS.

The final section was the Introduction to the Handbook, which acted as a user guide as to the function of each of the Handbook's sections.

The 1998-issue ERH thus consisted of the following documents:

- Introduction to the Handbook (Instructions for Handbook Use)
- Detailed Strategy Document (Global Considerations)
- Outline Method Statement (Guidance Flowchart)
- Decision Tree (Technique Selection)
- Detailed Design (3 Toolkits) (Technique Description)
- Vendor Costs

Other sections were indicated in the introduction but not included at this stage.

TESTING THE HANDBOOK

Initial Road Test

The initial ERH was 'road tested' against a theoretical case study, as suitable real life case studies were either too historical or *sub judice* and unable to be used in practice. The theoretical study was as follows:

> An incident results in a container of 'Germanic Acid' (a fictitious chemical) contaminated with Sr^{90} being spilt near to a crossroads of two main routes through site. A pipe bridge runs over the top and the main rail line for site also runs close to the crossroads. The container and bulk surface contamination have been removed.
>
> Contamination has seeped through the top layer of stone chippings and is now bound to the soil in the unsaturated zone to a depth of 50cm. The contamination is located near to the road way under the Pipe Bridge and extends laterally under the railway line. The measured atmospheric concentration of 'Germanic acid' at the site is near to occupational limits. The presence of the radioactivity in the area is increasing worker dose uptake. Normal operations are disrupted as a result of access restrictions due to increased dose at main crossroads.
>
> Constraints on remediation include:
>
> - Traffic must not be impeded for any length of time;
> - The rail link can be taken out of service, but not for extended periods;
> - There are height restrictions in the area due to the presence of the pipe bridge;
> - There is also a restricted working area due to the need to allow some traffic to continue using the roads;
> - There are no public issues as it is a localised on site problem;
> - The Regulators do not permit the UK LLW Repository to accept wastes containing 'Germanic acid'; and
> - The contamination is mobile, and must not be allowed to migrate vertically into the aquifer."

The expected outcome was that an in situ technique would be deployed to reduce Germanic acid levels and that some shielding would be necessary to reduce dose uptake levels.

The actual road test resulted in the selection of techniques not included in any of the Toolkits! (The solution reached was to take the rail line out of service, and re-lay/extend the concrete base until it performed all the functions of rail line foundation, water intrusion barrier, and shielding.)

It also highlighted a number of formatting, standardization and procedural improvements to the Method Statement flowchart in order to make it more understandable and user friendly. The changes requested included a road map to indicate the overall flowchart procedure, avoiding preconceived ideas about how it would be used in practice.

In addition to the formatting changes, a list of contact points for specialized information (e.g. company experts, managerial contacts, external vendors, etc.) was requested.

ERH Handbook Structure (II)

The ERH retained the modular format as before, but a number of sections were modified or added in response to the initial road test.

Firstly, the Outline Method Statement was revamped into the Detailed Method Statement (DMS), incorporating the formatting, standardization and procedural changes requested. An overall road map was added in order to specify the order of flowcharting steps. The Decision Tree was then deleted, as it had effectively been superseded by the changes to the DMS.

The Detailed Design Document was updated with the additional techniques identified. (Note: these included items such as 'Dig and Tip', a.k.a. 'Muck and Truck'. Their absence was due to them being considered disposal or storage options rather than techniques in their own right.)

The revised 1999-issue ERH thus consisted of the following documents:

- Introduction to the Handbook (Instructions for Handbook Use)
- Detailed Strategy Document (Global Considerations)
- Detailed Method Statement (Guidance Flowchart)
- ~~Decision Tree~~ ~~(Technique Selection)~~
- Detailed Design (3 Toolkits) (Technique Description)
- Vendor Costs
- Useful Information

Revised Road Test

The modified ERH was 'road tested' against a semi-theoretical case study, based on information from contamination of a reactor site. The semi-theoretical study was as follows:

> The Site has been used for a number of years for power generation, and has a number of reactors and associated support infrastructure (fuel ponds, etc.) on site. Contamination on site comes largely from Cs^{137} associated with spillage/leakage from the fuel ponds. Site geology has been characterised and was detailed.
>
> The contamination consists of plumes located in the Drift stratum with a combined volume of 100-1000 m^3. The impermeable nature of the site geology means that groundwater contamination is not significant. Flows of perched groundwater are towards the sea and a very substantial dilution occurs before contamination could affect the biosphere.

Remediation is necessary as construction work is planned in the contaminated area

- Modelling has shown that Cs^{137} is strongly bound to micaceous materials, and a progressive fixation onto the clay materials is expected. This leaves a very small proportion (<15%) for plant uptake or transport through the soil. Approximately 80% of total contamination is bound in the top few centimetres of soil.
- The Regulators are neutral on the question of remediation, provided that no breach of licence or operating conditions occur and that the solution is ALARA.
- A local pressure group is campaigning for 'something to be done'.

The second road test resulted in a number of actions:

- Physical removal of the contaminated soil and local storage in ISO freight containers on part of the site, freeing the remainder for construction without timescale constraints.
- Evaluation of a number of ex-situ processing technologies without timescale constraints to determine the optimum volume reduction method (unspecified in the worked example).
- Active engagement of local stakeholders in the decision process to develop a wider public consensus on the approach to implementation.

Minor modifications were identified in the clarity of the Detailed Method Statement, which were incorporated. An index was also requested, to improve ease of reference.

The successful application of the ERH to the semi-theoretical case study then permitted the creation of an Action Plan, detailing the logistical and managerial stages for converting the selected remediation technique into 'on the ground' remediation.

The Action Plan and Case Study information were then included as worked examples in the ERH.

CURRENT STATUS

Structure of Handbook

The current edition of the Environmental Risk Handbook is divided into a number of modular sections, permitting updating without having to re-issue the ERH in its entirety.

The sections present in the 2002 edition are as follow:

A. Introduction to the Handbook
B. Detailed Strategy
C. Detailed Method Statement
D. (was Decision Tree, now not used)
E. Detailed Design
F. Outline Costs
G. Action Plan
H. Case Studies
I. Useful Information
J. Index

Sections A & B cover the overall strategy and aim to ensure that the approach taken includes consideration of the 'wider picture' – insofar as remediation actions or inaction should not have a detrimental effect elsewhere either on or off site.

Section C is the application road map, covering the steps to be undertaken in response to the ETE. It is a descriptive method, avoiding the prescriptive 'Decision Tree' approach. Sections E & F underpin this; they cover the favored and backup remediation toolkits and associated costs.

Sections G & H cover the historical information pertaining to previous applications of the ERH in terms of planning and logistics; the aim is to provide a repository of case history to avoid the 're-inventing the wheel' syndrome.

Sections I & J provide the background information on internal/external contacts, sources of information, glossary and index.

Integration of the ERH into the BNFL Health, Safety, Environment and Quality (EHS&Q) regime is ongoing. The current issue ERH will be also be submitted for external peer review during 2002.

Comparison with non-nuclear equivalent

It is interesting to compare the ERH against a non-nuclear equivalent [2].

In both cases a modular format has been adopted. The main areas are overall strategy; problem definition and characterization; identification of suitable response (intervention or non-intervention); application of response; and an overarching monitoring and permitting regime.

The robustness of the methodology adopted has thus been confirmed by the convergent evolution of the cited reference.

CONCLUSION

The Environmental Response Handbook has expanded from the initial requirement for a limited, reactive Contingency Plan Handbook, and matured into its current open, proactive form that is being integrated into BNFL's management systems. This proactive approach permits the engagement of internal, regulatory and other external stakeholders into the decision process.

Although originally designed for the Sellafield site in the UK, feedback from within the BNFL Group has indicated its suitability for adaptation to other regulatory regimes and sites.

Application of the ERH methodology is suitable throughout the nuclear industry.

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY "Technologies for Remediation of Radioactively Contaminated Sites." IAEA-TECDOC-1086. IAEA, Vienna. (1999)

[2] ANDERSON, T. et al "Development of an Environmental Risk Management Handbook for Australia and New Zealand". Proceedings of the CSCS ASCE Environmental Engineering Conference, pp369-379. (1999)