A HOLISTIC APPROACH TO CONTAMINATION REMEDIATION

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Introduction

This paper looks at the process by which a development master plan and phasing plan are produced for a contaminated site. In particular it argues that contaminated land should be considered alongside other engineering and planning issues in a holistic process that seeks to minimise any adverse impacts arising from the presence of contaminated soil or groundwater.

Remediation of contamination on a development site often requires considerable effort to be expended to characterise it, assess its possible impacts on the environment and human health and then carry out appropriate remediation. This process can be time consuming and costly. Because of this it can affect the financial viability of a development and at the very least increase early development costs, impact negatively on cash flow and lengthen the time required to develop a site. For these reasons contamination should be a significant factor in project planning and should be integrated into the planning process to ensure that its implications are properly understood.

Very often however, assessment of contamination and its remediation is packaged up separately and considered only in the context of an already developed master plan and programme for development. This paper sets out to demonstrate how consideration of contamination, collectively with other engineering and planning issues, can lead to integration of the works necessary for site development in a way that minimises the effects of site constraints and maximises development potential.

The following sections look at some of these issues and the impact they can have on site development.

Intrinsic and Management Site Boundaries

Redevelopment options for a site will always be constrained by a set of boundaries specific to a site. This is particularly true of remediation options. These boundaries can be divided into two types: intrinsic and management (Nathanail et al). Intrinsic boundaries relate to the physical properties of the site, for example: the geological and hydrogeological conditions; the nature and location of contamination; the presence and proximity of sensitive environmental and/or human receptors; accessibility; services; archaeological features etc. These are properties of the site and essentially define the problem, its significance and physical constraints on solutions.

Overlaid on the intrinsic site boundaries are usually another set of boundaries that relate to the management of the site. These include ownership boundaries, use of the site before, during and after remediation, the objectives and interests of stakeholders, time and budget constraints etc.

For a site unconstrained by management boundaries there will be a set of remediation options that will deal with the risks to the environment and surrounding human receptors, that will include the most effective and economic solution. However management boundaries often introduce a layer of additional constraints and complexity that is not of a physical nature but has serious implications for the viability of some remedial options and which can lead to significant additional costs. For example, where an area of contamination crosses an ownership boundary there may be issues of cross-boundary migration after clean-up of one site. This may result in the need for barriers at the ownership boundary. Similarly time constraints may rule out some remedial options such as insitu biodegradation in favour of faster but more costly solutions such as dig and dump. A site's proposed end-use may introduce the requirement for an increased standard of clean-up above that required to overcome intrinsic environmental risks to offsite receptors.

Intrinsic site boundaries are difficult or impossible to change. Some, such as access difficulty, might be removed but in general they are fixed and must be accommodated in risk assessment and development of remedial solutions. Management boundaries on the other hand may often be changed. For instance, land ownership boundaries may be removed by purchasing land or by cross ownership agreements to jointly remediate land straddling a boundary. Timescales and site end-use may be changed.

It is therefore important to understand the factors that, for a particular site, are controlling the viability of potential remedial techniques and the impact these are having on cost. For example, a developer may aim to have an apartment building completed within a given timescale. If it is increased by three months it may allow the use of a slower but cheaper remedial solution and the cost of remediation may be significantly reduced giving a better overall financial result. It should be noted that contamination remediation is not the only engineering work that may be impacted by management boundaries. For example, ground improvement by preloading and monitored settlement may be ruled out by a development programme or phasing plan that does not provide adequate time. This may potentially lead to significant additional foundation cost. The impact of existing and proposed management boundaries on technical remediation issues and the associated cost implications should therefore be explored and options involving changes to existing boundaries and imposition of new boundaries investigated.

Masterplanning

The presence of contamination on a site should be a major consideration in development of a master plan. The cost of remediation is likely to vary greatly depending upon the proposed end-use. Development of a site for housing with gardens will generally incur much larger remedial costs than development for a commercial end-use. The exception to this may be when the driver for remediation is environmental; for example to protect groundwater or surface water.

Offsetting the cost of remediation is the value of the remediated land. It may be the case that a particular piece of land, for example on a waterfront, is particularly valuable for housing and that the value obtained by cleaning a site to a residential end-use standard more than compensates for the cost of remediation. However this will not always be the case.

For a given site there will be a number of possible master plans each with different remediation requirements and cost and each delivering different land values. There may also be other costs linked to the past site use such as buried obstructions (e.g. foundations and basements) and areas of poor filled ground as well as natural ground conditions, which may have different cost implications for different development options.

Clearly it would not make sense for a master plan to be dictated purely in relation to constraints related to contamination and other physical characteristics, however it should be recognised that a master plan is a set of management boundaries, as discussed previously, which can have a considerable impact on the cost and time required for site redevelopment. The implications of imposing these boundaries should therefore be clearly understood and any adverse impact taken into account. As noted above such adverse impacts will not necessarily be unacceptable as there may be other, larger, benefits such as increased land value and profit that will offset them. They should however be defined and understood.

Development Phasing

It is normal for development of large sites to proceed in stages. This allows generation of cash flow and profit to finance later stages. Areas of a site requiring contamination remediation will invariably be the most expensive to develop. It therefore makes sense, in general, to consider this in development phasing so that these areas are developed later when cash has been generated from earlier phases. Delaying redevelopment of contaminated areas can also provide the time necessary to implement slower but more economical remediation techniques. This can also be true of other ground related engineering issues such as ground improvement. Consequently phasing of development taking account of these issues can be an important factor in minimising the cost of redevelopment.

Site-Wide Assessment and Remediation Strategies and Economies of Scale

For a large site there is often a tendency to deal with contamination a bit at a time perhaps related to a phased development as discussed above. However, there can be significant benefits in taking a wider approach. Certainly investigation and assessment of contamination should be a site-wide activity. A large site may have a number of different areas of contamination. These may be widely spaced or close together, they may be of a similar nature or different and they may be of similar or different levels of severity and risk. They may also interact with one another e.g. groundwater contamination plumes. It is therefore important to develop a conceptual site model for the whole site on which to base design of remedial solutions.

This conceptual model is obviously the fundamental input information for the development of a remediation strategy for the site but it should also be a fundamental input parameter in the development of a master plan and phasing of development as discussed in the previous sections. In this way a site-wide remediation strategy may be developed as part of (not to fit in with) the site master plan. This can allow areas of like contamination to be remediated together, resulting in economies of scale and use of the most cost effective remedial techniques. It can also allow strategies to be developed to move material around a site and for these to be integrated into general civil works as described further in the following sections of this paper. A site-wide remediation strategy integrated into the master plan, phasing and other engineering works can therefore minimise the costs and time necessary to remediate a site. By contrast trying to develop remedial strategies for small areas to suit a master plan, phasing and engineering design that has been developed independently will inevitably lead to higher costs and longer timescales.

Recycling and Re-use of Materials

Many of the materials found on brownfield sites can be beneficially re-used in site redevelopment. These include concrete, stone and brick which may be crushed and screened re-used as aggregates and excavated materials. Excavated materials may range from topsoil, to rock to soft alluvium. Most such materials may be reused on a large redevelopment site in uses ranging from structural fill to landscaping. Retaining materials on site has a number of benefits including avoiding offsite haulage and disposal costs and avoiding the cost of importing fill materials. These savings mean that money can be spent on processing materials on site to get the best value from them. Retaining material on site instead of disposing of it also fits well with sustainability objectives: reduction of material to landfill; reduced carbon emissions from transport; reduced use of natural materials.

Retention of material on site often requires careful thought and design in the planning stages of a project. If a project is designed without thought given to re-use of materials, such materials will generally end up being 'surplus'. However if plans are developed to incorporate use of such materials i.e. adjusted ground levels, landscaping features and specification adjustments to allow use of recycled materials, reuse of materials can become an integral part of the development plan. In such a plan it is also important to consider the site as a whole. Some parts of a development may generate large quantities of material e.g. buildings with basements, others may require fill material e.g. for building platforms, road embankments or general fill. It is therefore important to consider these issues in development of the master plan and consider where excess materials will be generated and their nature to match them with where materials will be needed and their requirements. If this can be achieved considerable economies and enhancement of a development's sustainability credentials can be achieved.

Strategies for Re-use of Contaminated Soils

Strategies for re-use of excavated materials as discussed in the preceding section will obviously be affected if the materials are contaminated. However this does not mean that such materials cannot be re-used. It will however limit where and how they can be used. It also leads to the need for comprehensive data on the nature and extent of contamination. This information may be used to classify soil in terms of its suitability for use in different end use scenarios. If a site has a variety of end-uses planned, soil with contaminant concentrations higher than acceptable for a residential development area may be moved from such an area to a commercial development area where they are acceptable. Clean soil from one area of a site may be use as capping of contaminated soil in another. Obviously some soil may be contaminated to such a degree that remediation is required for any use and there will also be environmental considerations that may require enhanced clean-up levels. However, the level of clean-up of such soil that is necessary may be minimised by re-using it in the least sensitive area of the site. In this way movement and re-use of contaminated materials in less sensitive locations can remove or reduce the need for expensive remedial treatment of soil or offsite disposal.

As discussed previously this sort of optimisation of materials use can only be achieved within a site wide remediation strategy integrated into the site master plan.

Integration of Contamination Remediation with Other Civil Works

Many redevelopment sites require a range of civil works that are unrelated to contamination. These can include ground improvement, earthworks, and infrastructure works. The requirement for these works should be considered alongside the requirements for contamination remediation works. If considered in isolation these requirements may conflict with each other. For example there is no point in improving ground that is later excavated for contamination remediation. Similarly a capping remedial solution will be invalidated if there are later to be significant earthworks. Some ground improvement techniques such as vibrated stone columns can introduce contamination migration pathways that have not been allowed for in remediation design. All sorts of excavations can generate contaminated soil arisings that cannot be incorporated on site if remediation is already completed.

It is therefore beneficial to consider all operations in the ground collectively and within the context of development of the overall master plan and remediation strategy for the site. Some remediation techniques can be combined with ground improvement. For example soil stabilisation techniques can fix contamination and improve soil strength. For contaminated loose fill material an exsitu remediation technique can combine excavation and recompaction of the material thereby also providing ground improvement. Consideration of contaminated soil that will be generated from excavations for ground works can allow their accommodation on site if suitable areas of the site are left low to receive them avoiding the need to dispose of them off site. Integration of contamination remediation and other necessary civil works can therefore significantly reduce overall development costs and timescales.

Site Investigation

From the foregoing discussions three things become evident in respect of information relating to the properties of the ground.

- It is needed early in the master planning/design process.
- Good quality and sufficient quantity of information is required.
- Information is required on the physical and contamination characteristics of the site.

In practice, in many cases, the quantity and quality of information is poor and it is difficult to make accurate assessments of the remediation and engineering works required to develop a site. It is also common for information to be available only on geotechnical properties or contamination. Information on both is required to develop a complete picture of redevelopment requirements. It is therefore often difficult to optimise master plans and phasing. If there is insufficient information, additional site investigation will have significant benefits in enabling the sort of processes described in the preceding sections. There is a cost associated with obtaining the required information but it will have to be expended at some stage and the value of early information more than offsets the cost of early expenditure of the relatively modest sums required. Costs can be maximised by combining geotechnical and contamination investigations especially if contamination of soil or groundwater extends to depth and the very act of carrying out a combined investigation promotes early consideration of these two important factors in a holistic manner. Trying to save money on site investigation by limiting its scope or delaying its implementation is usually a false economy.

Risk Assessment

Quantitative risk assessment is often seen as a last resort for difficult sites when simpler (and cheaper) assessment processes cannot be used. In some cases this is reasonable, however in many cases quantitative risk assessment may be used as a tool in development of an economic master plan. Risk assessment can allow generation of less onerous remedial standards than conservative generic standards based on conditions that may not apply at a given site. It can therefore allow a reduced scope of remediation in some cases. It can also allow consideration of more complex remedial solutions. Of course this can only be done if there is sufficient quality data. This need for data will extend to detailed information on ground and groundwater conditions if a hydrogeological risk assessment is to be undertaken. This information can be obtained in the sort of combined contamination and geotechnical investigation discussed earlier. Groundwater contamination can present a very expensive problem in respect of its remediation and a good hydrogeological risk assessment can allow remedial solutions to be tested and optimised. This can include low cost options such as monitored natural attenuation. This approach to design of remedial solutions using quantitative risk assessment as a tool to model and confirm the effectiveness of solutions can ensure that remedial effort is focussed and cost effective. Adoption of generic and conservative remedial targets for soil and/or groundwater may be very costly and expenditure of relatively small sums on investigation and risk assessment can result in considerable time and cost savings. The assessment process and agreement with regulatory authorities (including any resource consent requirements) is however likely to take longer than if a conservative strategy is adopted and this needs to be taken into account in programming.

Innovative and High Technology Remedial Solutions

Use of innovative and technology based remediation techniques requires more design input than a simple technique such as 'dig and dump'. However techniques such as insitu and exsitu bioremediation, soil stabilisation, soil vapour extraction, and others are established techniques and allow remediated soil to remain on site. This can save considerable sums of money that would otherwise be spent on offsite disposal. This is likely to become a more significant factor as landfill costs rise. Use of such techniques requires more knowledge of ground and contamination characteristics than simpler solutions. Some may also take longer to implement with implications for development programmes. Planning is therefore required to integrate these techniques into the overall master plan and phasing. If such consideration is not given, inevitably opportunities will be lost through the development of 'management' boundaries, such as timescales that preclude the time necessary to develop and implement them.

Conclusions

The preceding sections of this paper have attempted to set out factors that need to be considered in the planning for redevelopment of a contaminated site to minimise the impact of the contamination on cost, redevelopment timescales and other outcomes. Each has been discussed separately for clarity but the main conclusion of this paper is that all of these factors must be considered collectively. They all interact and overlap and exclusion of one from the decision making process is likely to result in benefits being lost. It is difficult to 'bolt on' something like recycling and re-use of demolition materials and 'surplus' soil to a finalised development plan. The only stages of the process that can be effectively separated are site investigation and determination of the intrinsic and management site boundaries. These are a fundamental prerequisite to the work that follows.

Figure 1 shows the process schematically. This process is by its nature 'messy' and needs good project management and control by the client. The process must be iterative and the key requirement for a successful outcome is the early involvement of all the relevant professionals, from architects and planners to civil and environmental engineers to financial advisers and of course the client. This involvement is best in face to face discussions. It is important that each member of the team understands the constraints imposed by the other's discipline. The client's requirements and objectives for the project are central to development of the master plan and all the other factors and input of each team member must relate to these. The client may impose management boundaries during this process and his team can advise him on the implications of his decisions. In this way a holistic master plan can be developed that meets the clients requirements and maximises the opportunities of integration of the different works required.

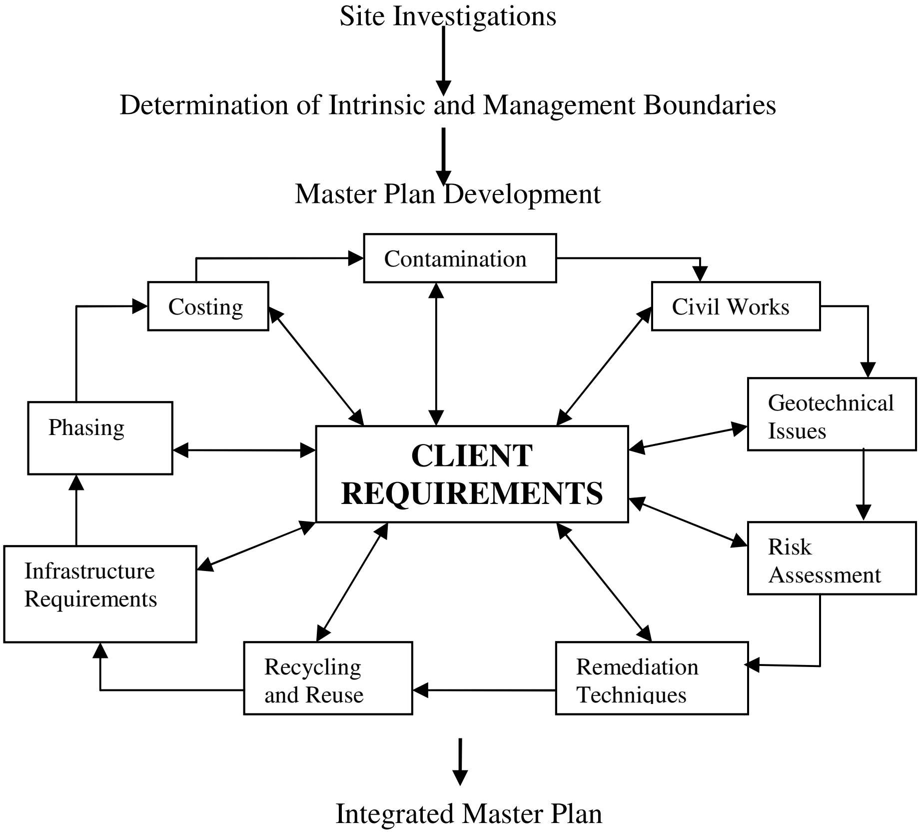

Figure 1: Development of an Integrated Master Plan for Redevelopment of a Contaminated Site

Project Example: Cardiff International Sports Village, Wales, UK.
This is a 35ha site forming a peninsular within the freshwater lake formed by the Cardiff Bay barrage. The site has a history of industrial and commercial uses including a licensed landfill, waste transfer stations, railway sidings, wharves, scrap yards and an oil terminal. The site was extensively contaminated with metals and hydrocarbons. A site-wide remediation strategy was developed and implemented that included the following features.

- Exsitu bioremediation of 28,000m^3 of hydrocarbon contaminated soil.
- Insitu bioremediation of 17,000m^3 of hydrocarbon contaminated soil and groundwater.
- 300,000m^3 of earthworks.
- Dynamic and vibro compaction of the landfill.
- Capping and gas and leachate drainage to the landfill.
- 1,600m of sheet pile river edging.

Prior to development of the master plan there were two phases of combined geotechnical and contamination site investigation that defined the extent and nature of contamination and the geotechnical and hydrogeological conditions. The intrinsic site boundaries were well defined in terms of the site's hydrogeological setting within Cardiff Bay and distinct zones of different contamination including hydrocarbons and landfilled waste. The master plan was developed to take into account such factors as the landfill and its associated development problems. The main hydrocarbon contaminated area was designated for residential end-use despite the high remedial standard necessary because of its prime waterfront location and the land values that could be achieved and the fact that the main driver for remediation was protection of groundwater and surface water. Remediation costs were also minimised in this area by re-use of the soil excavated and treated by exsitu bioremediation as capping to the landfill which was subjected to ground improvement (compaction) prior to capping and designated for commercial (retail) use. Cleaner soil from old railway embankments (required to be levelled as part of general civil works) was used as fill in the housing area. In this way the contamination works were integrated with necessary earthworks including general levelling, capping of the landfill and the river edge works.

These works and movement of contaminated soil were set within a site-wide remediation strategy based upon quantitative risk assessment. The site was largely in one ownership and there were few cross boundary issues. The remediation strategy included natural attenuation of residual hydrocarbon contamination following insitu bioremediation that allowed the standards required to be achieved by the insitu bioremediation to be less onerous than they would otherwise have had to be. Risk assessment also allowed metal contamination to remain insitu with temporary capping placed in the remediation contract and final capping being placed by individual site developers to suit their developments. These remediation strategies clearly resulted in ongoing contamination management issues including some cross boundary issues after sale of the site into smaller parcels. However these were acceptable to developers because of the agreements already in place with the regulatory authorities.

Development of the site was phased. Initially a relatively uncontaminated and valuable area of the site was separated from the main site and developed for housing generating early cash flow to finance the main remediation works. Within the main works remediation of the landfill area was programmed to be completed early to allow retail development to proceed. This site was also close to the main road and needed little internal infrastructure. The income generated from its development financed the road junction needed to provide access to the site. The main housing area, requiring more internal roading and subject to a relatively slow insitu bioremediation clean-up, was programmed for development later.

This project demonstrates how the remediation of a large contaminated site may benefit from a holistic site-wide approach to contamination and general civil works whilst maintaining a phased development approach that allows for generation of cash flow. This major civil and remediation contract had a value of about £15M and was completed in 22 months. The cost and timescale would undoubtedly have been greater if the site had been remediated on a piece by piece basis.

References

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