



## Drilling Fluids Waste Management in Terms of a Sustainable Environment

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This paper was prepared for presentation at the AADE 2004 Drilling Fluids Conference, held at the Radisson Astrodome in Houston, Texas, April 6-7, 2004. This conference was sponsored by the Houston Chapter of the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author/s of this work.

### Abstract

The traditional approach to drilling waste management is a process designed to take the cuttings and waste mud from a drilling operation and ensure that the end result meets current local environmental discharge regulations. Changing regulations and increasing public awareness, coupled with the concept of maintaining a sustainable environment are increasing the potential long-term liabilities associated with current waste management concepts and processes.

New technology is now available in the areas of drilling fluids design, fluid treatment and contaminated cuttings treatment which can dramatically reduce both the quantity of, and environmental risk associated with, contaminated cuttings and spent drilling fluid. In addition, application of novel techniques to recycle fluids and convert contaminated cuttings into agricultural or other commercially acceptable by-products can be carried out to eliminate the requirement for waste disposal. The net result of proper planning up-front and use of the applicable chemistries and resource management techniques is to meet or significantly exceed current drilling performance requirements, whilst pursuing the target of zero waste generation.

This paper presents a path forward where the potential exists to convert the remains of a drilling operation to a usable by-product, realizing the goals of zero waste and minimum long-term liability.

The authors evaluate the requirements for drilling fluid design, solids control, cuttings processing and final fate to ensure the process of zero waste generation can be optimized with acceptable economics and minimal liability risk. The authors also will present case histories documenting how this approach has been undertaken.

### Introduction

When facing new environmental regulations, waste disposal liability, and safety issues, oil and gas operating companies can benefit from "reinventing" their approach to waste management, instead of just slightly improving current technologies.

Market research shows an overwhelmingly large number of companies delivering drilling waste treatment services. These range from large, well-integrated service providers to straightforward disposal companies, as well

as small, single-technology equipment or service providers.

Despite the large number of service providers in the market, there is a common denominator regarding their business propositions. They offer improvements to existing, well-established, technologies or techniques. What some of these service providers do not realize is that when it comes to addressing long-term disposal liability, such incremental change is not sufficient for many of today's operators. These "better or improved" technologies treat symptoms, but not the underlying industry conditions.

"Reinvention" is not about changing what exists, but creating something new and totally different. When a business line reinvents itself, it must alter the underlying assumptions on which its decisions and actions are based. To "reinvent" a technology line or service proposition, the hidden assumptions must first be uncovered. The following are some of the "ground rules" that have been taken as the basis for the drilling waste management business environment that has typically been practiced to date:

- Selection and use of drilling fluids usually is made on technical grounds – improved drilling performance and lower well costs;
- Diesel and mineral oils commonly are used to minimize cost when invert emulsion muds would be the fluids of choice;
- Chloride-based salts commonly are chosen to improve the inhibitive performance of water-based muds and are used as the internal phase in IEM (invert emulsion muds) on the basis of cost;
- Land-farming, landfill, cuttings fixation, mix/bury/cover techniques, thermal desorption and re-injection are widely used for contaminated cuttings disposal

Although these assumptions represent the typical conclusions that members of a specific part of the waste management business have reached, it is a continuously changing environment. Embracing this change within

waste management, new ground rules are being developed as follows:

- Environmental disposal regulations are being tightened – reduced hydrocarbon residues, reduced toxicity, reduced salinity, lower conductivity, lower heavy metals;
- The total cost of drilling waste management includes more than just the immediate cost of managing the waste;
- Under the U.S. Comprehensive Environmental Response, Compensation, and Liability Act (Superfund), a company could dispose of its waste in an approved fashion today yet face remediation liability in the future.

### **Waste Treatment and Disposal Liability**

From the operating company's point of view, the most important aspect of drilling waste management is understanding liability in its full context. The engineered solution for managing both operational and liability issues represents the backbone of the proposed methodology.

To better understand the organizational context, two analyses were performed: the first identifying the current industry-wide, project-planning methodology (Fig. 1) and the second looking at the waste management and disposal liability inter-relationship (Fig. 2).

The current waste treatment and disposal planning concept invariably starts by addressing the scope of work and planning for the drilling fluid. The type of mud chosen usually dictates the needs for specific solids-control equipment. The solid and liquid wastes are then collected and treated, in attempts to minimize the amount of waste and maximize the amount of recovered fluid. However, typically it is not until this last step that the question of "*How can we dispose of these drill cuttings, has anyone got any good ideas?*" is asked. Frequently, by then, it is too late in the process to change the nature of the drill cuttings contamination. Thus, they usually end up in landfills or other commercial disposal processes.

The liability inter-relationship analysis shows that, in spite of delivering technology to make disposal compliant to current regulations, long-term liability is unaffected. In other words, the very moment any process end-products (e.g. drill cuttings) become waste, which has to be disposed of, the liability string becomes attached. This casts an entirely different light on the process.<sup>1</sup>

All of an operators' efforts to reduce liability by delivering improved technologies for waste minimization and treatment can be rendered pointless if the processed cuttings end up in the same landfill facility where less environmentally compliant operators are

disposing of their waste. The Superfund liability does not discriminate among the waste generators using the same waste disposal facility. All "contaminating partners" share the same responsibility for site reclamation. This is a common denominator for all drilling waste management technologies and processes, namely the inability to formally assess and control waste disposal liability.

Under the legal framework of the United States it is very clear that the final responsibility for waste disposal belongs to the waste generator (i.e., the operator). No waste management service provider can take over this responsibility. The methodology proposed in this paper – *Resource Management* – is all about liability assessment and non-disposal, especially beneficial reuse technologies. This provides a comprehensive tool for operating companies (waste generators) to first understand their ultimate liability and then take appropriate measures to control and minimize it. It represents a system where, using regulated processes, drilling waste disposal in the traditional sense can be avoided as the drilling waste materials generated are being re-used. If there is no waste to dispose, the largest portion of long-term liability is avoided (Fig. 3), although there will still be a certain element of liability.<sup>2</sup>

As with any new methodology, *Resource Management* must be defined. It represents the project-planning process and the required integrated services that, by using the right combination of drilling fluid and treatment technology for specific environmental regulations, aims at converting the drill cuttings and associated drilling fluid into a beneficial reuse product without disposal requirements.

*Resource Management* approaches project planning in an entirely different manner from before, namely by means of *Reverse Wave Engineering*. This alternative method starts at the end of the process determining the environmental and legislative targets that need to be met and/or are targeted. Afterwards, fluid formulations and treatment technologies are designed to simultaneously meet the technical, financial and environmental targets for the well in a more holistic approach (Fig. 4).

### **Resource Management and Reverse Wave Engineering**

The planning process for a *Resource Management* project is controlled by compliance to either *waste disposal* or *beneficial reuse regulations*.

For true beneficial reuse, it is not only about assessing the long-term liability frame, but choosing the right drilling fluid, solids control and cuttings/fluid treatment package. This approach shifts the focus from not generating drilling waste to producing products that can be beneficial reused in the environment. Figure 5 presents the *Resource Management* methodology structure with the planning package and technology selection. This is a process that crosses all available

drilling technologies and utilizes all the current advances in drilling fluids chemistry, solids control, volume minimization and beneficial reuse treatments.

When long-term liability is not the driver for a specific project or operator and compliant disposal can be sufficient, then Resource Management can be applied for assuring compliant disposal according to waste management regulations (Fig. 6).

### Base Fluid Chemistry

It is important to consider how the final waste disposal method will function with the base fluid used in the continuous phase of the drilling fluid. For example, under the right environmental conditions, bacteria are very efficient at degrading many types of hydrocarbons. However those compounds that bacteria cannot readily degrade can delay the final remediation and closeout of the site, thereby increasing the overall cost of the operation.<sup>3,4</sup>

Alternatively, if the drilling fluid is optimized for its biodegradability by using a base fluid that does not contain any aromatic, cyclic or branched components, the treatment times can be significantly reduced, since there is no requirement to get rid of or reduce the "humptane" fraction present in a diesel or mineral oil.

### Brine Phase Chemistry

Perhaps a more difficult problem to resolve onshore is the impact of the brine-phase chemicals from the treated drill cuttings on the receiving environment. The effects of inorganic salts on the electrical conductivity of soils and the need to protect groundwater supplies is well known and understood, yet there presently is no real way to degrade the problem salts as, strictly speaking, inorganic salts do not degrade. While such chemicals can be treated by converting to immobile forms or diluting to below toxic limits or washing out of the waste, this does not necessarily eliminate the problem and there might still be an outstanding liability issue. Additionally, there is a limit to how much dilution can be done, thus non-toxic levels may not be able to be reached.<sup>3,4</sup>

Thus, it would seem that the best option is to engineer these materials out of the drilling fluid if at all possible by using a high-performance, salt-free fluid or an alternative salt that is biodegradable (e.g. acetate or formate), or one that is utilized during the treatment process (e.g. nitrate-based salt which can be used to supply inorganic nitrogen as part of the fertilizer requirements for bioremediation).

### Environmentally Compatible Drilling Fluids

The philosophy behind the development of such fluids was not to design a system that merely posed a neutral or negligible impact on the environment, but rather one that would prove beneficial. Thus, the goal was to carefully select the individual components of the

fluid system, including the base fluid, emulsifiers, internal phase (salt and water), weight material and fluid-loss additives, to allow efficient drilling and generation of drill cuttings that can be used to actively enhance soil quality and subsequently support improved plant growth.<sup>5,6,7</sup>

In the early stages of the development, environmental tests were carried out on various base fluids and complete drilling fluids with different internal phases. The fluids were thoroughly tested for their drilling performance characteristics (fluid properties, technical limits, contamination tolerance, engineering control etc) prior to extensive environmental testing. Newer environmental test techniques included: Alfalfa seed emergence and root elongation, earthworms (*Eisenia fetida*) toxicity, Springtail (*Folsomia candida*) toxicity, Microtox bacterial toxicity and aerobic biodegradability (respiration rate and hydrocarbon loss in moist soil.)

All of this led to a new, linear paraffin-based, drilling fluid system which was designed to completely and rapidly degrade by natural bacterial action, leaving zero or minimal organic residues. The fluid is designed to perform without relying on chloride-type salts for the brine phase. In addition, replacing the barite typically used to control density in the drilling fluid with the iron-based mineral hematite was shown to benefit iron-deficient soils if the cuttings from the bioremediation processes are re-used.

Unique to the development program was the use of earthworms to transform the waste generated by the system into a commercially beneficial by-product.<sup>14</sup> To date, more than 1,500 tons of cuttings have been "worm farmed" in New Zealand, reducing the total petroleum hydrocarbons (TPH) to almost background concentrations under the correct conditions and application rates.

### Worm-Based Bioremediation

The idea of using earthworm-based vermiculture to enhance the bioremediation process and convert the drill cuttings into an "organic" fertilizer (Resource Management) was proven out in the New Zealand field test.<sup>8,9</sup>

In this example, the paraffin-based system described above was used in an environmentally sensitive area, which featured extremely reactive shales that had historically created serious drilling problems with the water-based drilling fluid systems used previously. The formation of mud rings, significant borehole ballooning, borehole washout, induced fractures, unsuccessful logging runs, high fluid costs and overall hole instability were but a few of the host of problems the operator had encountered in the area. The paraffin-based system not only dramatically reduced the drilling problems encountered in earlier wells, but also is credited with enhancing production from the tight gas sands.

Combining the paraffin-based fluid system with

worm-driven remediation decreased the hydrocarbon concentrations on cuttings from 4,600 mg/kg (dry weight) to less than 100 mg/kg dry weight, remarkably in less than 28 days.<sup>8,9</sup>

While worm farming, or vermiculture, is well established as a method of treating organic wastes in many parts of the world, the New Zealand experiment was the first time it was applied to drilled solids. The success of the project is based upon carefully formulating the fluid to deliver optimum biodegradability and minimum toxicity to the earthworms, whilst ensuring good husbandry of the "livestock."

However, any one solution to the problem of what to do with drill cuttings may not always be applicable to another location and environment. It is a key part of the planning process to determine the required end points, technical, regulatory and political, and use these as part of the decision-making process in optimizing drilling fluid selection and choice of the most appropriate waste management technique.

### Conclusions

Any technology vision and strategy should have strong anchors set into the business reality and should entirely adhere to industry core values. Worldwide exploration and production (E&P) operators are expecting integrated methods of preventing and minimizing existing waste management problems (*i.e.*, waste generation, control and treatment). For maximum success, emphasis should be placed on assessment and planning rather than individual waste management products and technologies. The applied methodology should be focused on in-process responsive control and treatment methods rather than proposing an after-the-fact cure.

The identified key waste management needs fall into the general categories of engineering tools. The proposed Waste Management Assessment and Planning Concept (Resource Management and Reverse Wave Engineering) is geared towards solving waste-management problems through a logical developed process and using best practices and knowledge.

One important question to answer is whether Resource Management adds any value to the E&P business. The most advanced level of technology integration is *advice* and *partnership*. E&P operators feel the closest bond to those who have helped them learn, who have aided them in avoiding problems, and who have improved their public image. Resource Management creates a logical frame and a toolbox for E&P operators to assess their own liability and decide on the degree of control they would like to take in the disposal or beneficial reuse process.

A Resource Management technology application will allow E&P operators not only to meet performance requirements but also to increase a positive environmental visibility, compliance and long term

liability control. Other benefits could be: improved drilling performance, health and safety, near-zero impact for local community, and optimum cost for disposal versus managed liability.

### Acknowledgements

We thank the management of both ChevronTexaco and M-I SWACO for support and permission to publish this paper. Special thanks go to Mary Dimataris and Jim Redden from M-I SWACO for professionally revising this paper.

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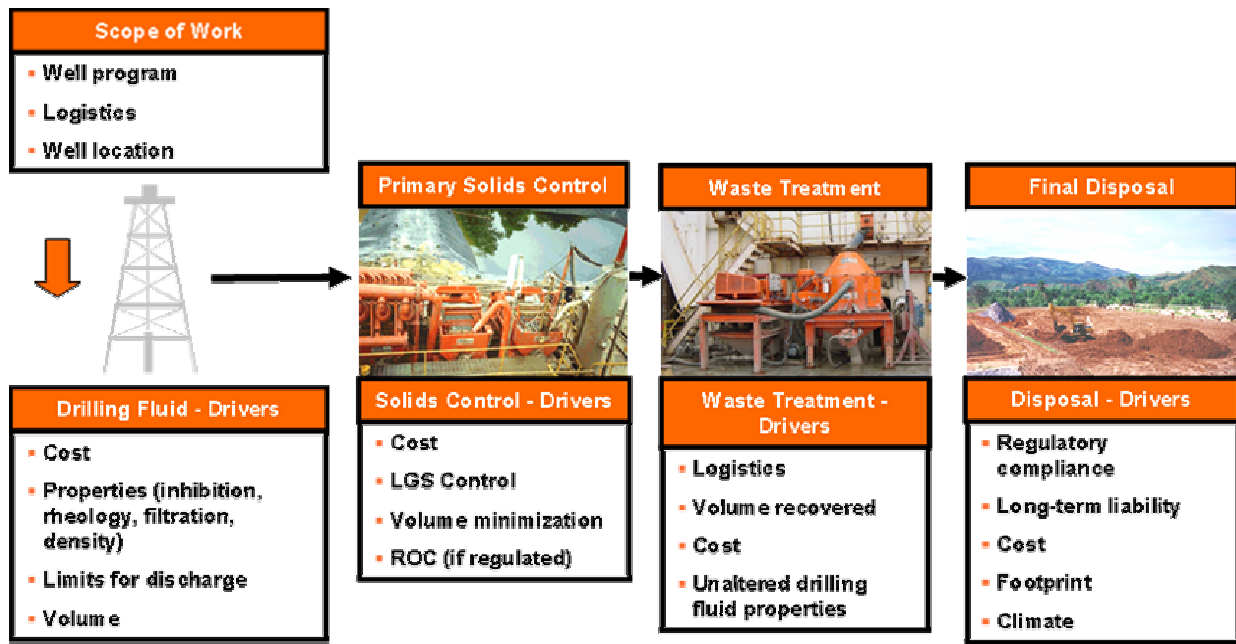


Fig. 1. Current project planning methodology

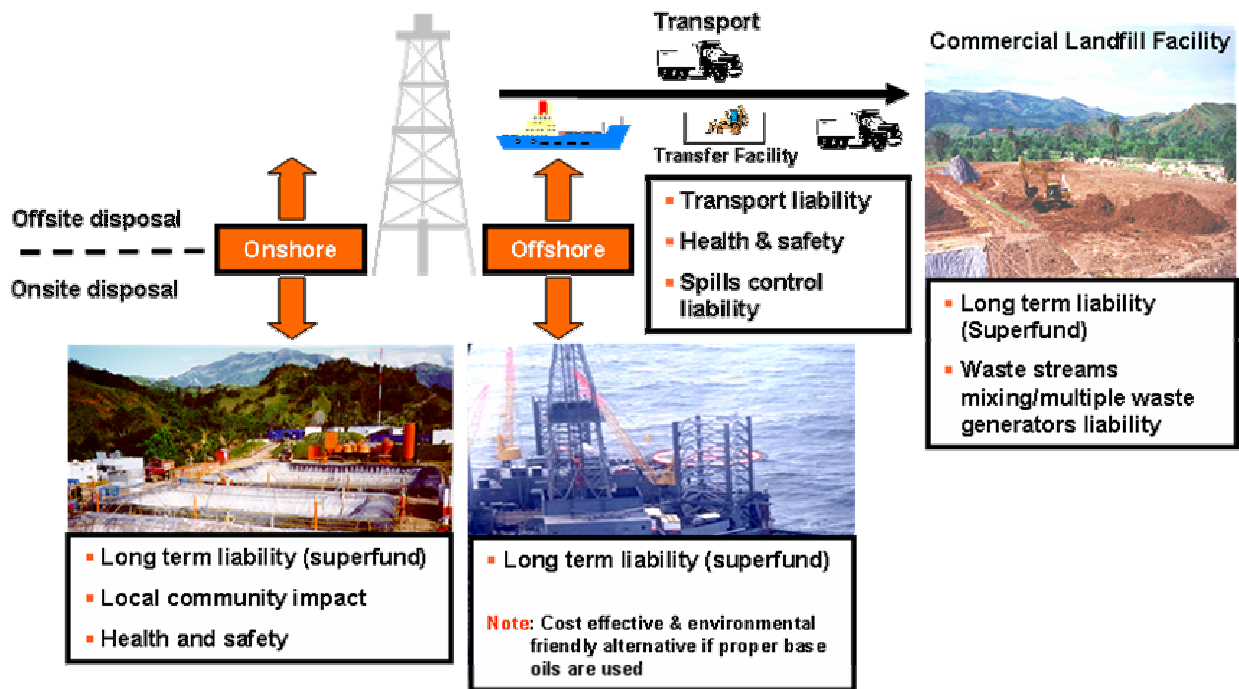


Fig. 2. Operational and Waste Management liability inter-relations

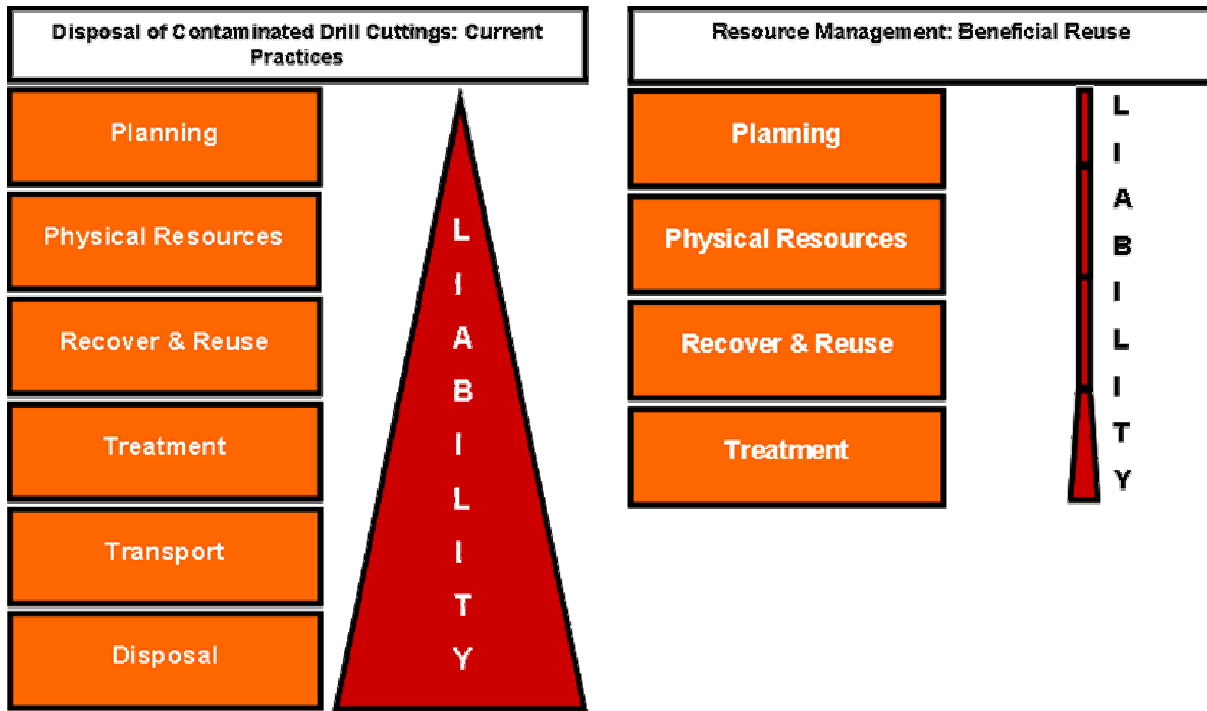


Fig. 3. Operational and Waste Management liability inter-relationship

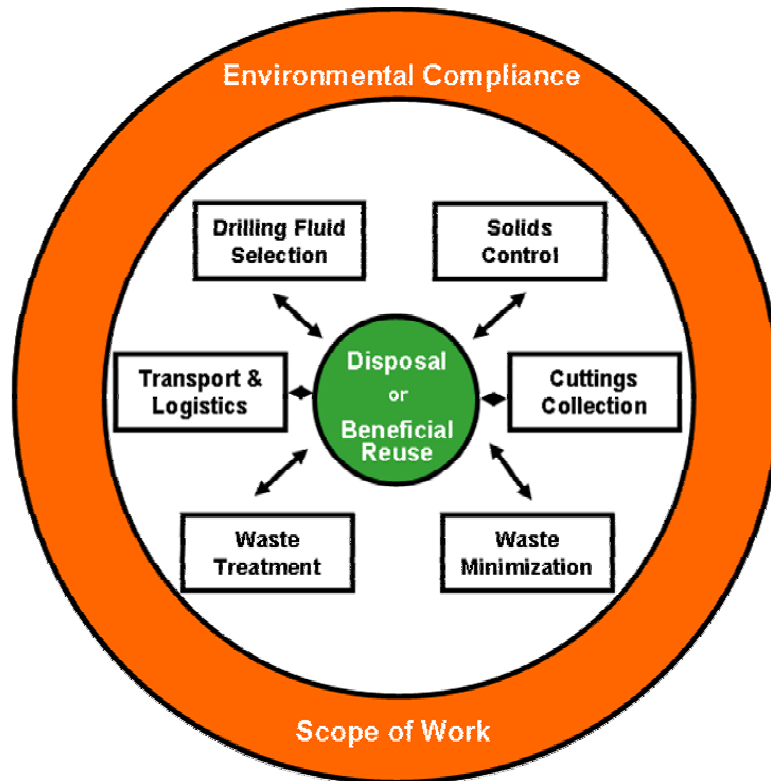


Fig. 4. Reverse Wave Engineering for Resource Management

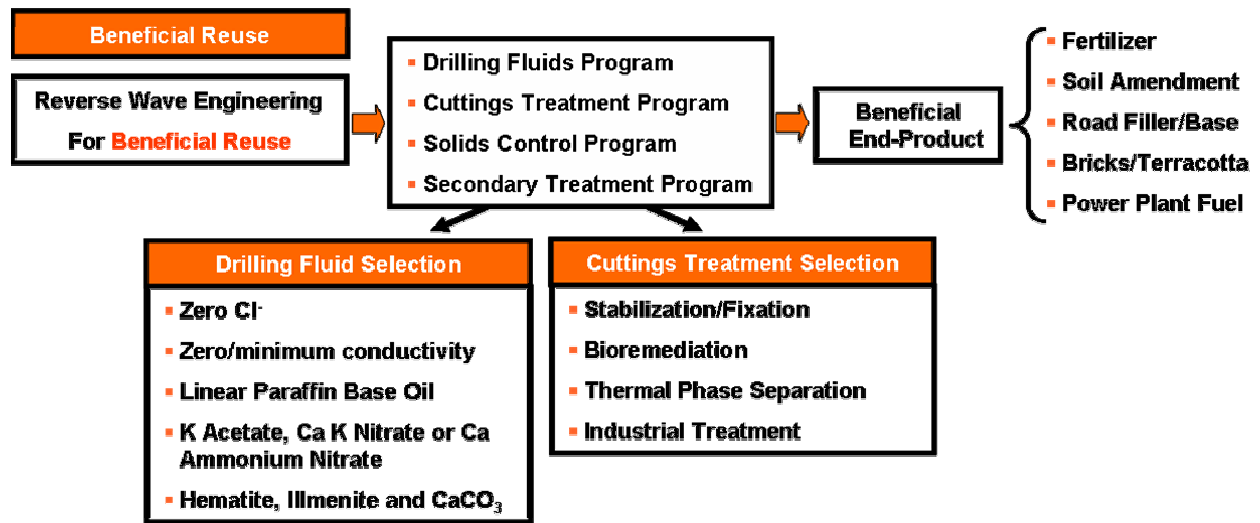


Fig. 5. Resource Management applied as Beneficial Reuse



Fig. 6. Resource Management applied as Compliant Disposal