ASPHALTIC INCORPORATION™ OF CRUDE OIL AFFECTED SOILS

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ABSTRACT

This study was conducted by Raba Kistner Consultants, Inc. (RK) on crude oil affected soils (COAS) originating from an oil production location in the IPEC Tall Grass Prairie Project area known as the "Redwood Tank Site".

The objectives of the study were to determine the environmental, engineering and economic feasibility of recycling COAS as an ingredient in the production of specified grades of non-hazardous, asphalt paving materials for use on oil field applications and secondary roads.

Asphaltic Incorporation™ (AI) is a proven environmental remediation method of utilizing affected soils as the fines component in the production of cold processed recycled paving materials. To date, the majority of AI™ projects have involved the recycling of materials from industrial or "downstream" facilities involving product releases from refineries, pipeline and distribution terminals, tank farms, UST sites and petrochemical locations. Historically, oilfield remediation has been limited to landfill, or other disposal, and variations of "landfarming". Little work has been performed in this sector that would be of the resource recovery nature.

Innovative Resource Recovery Remediation™ ($R^{3™}$) methods can produce a lower net cost compared to other remedial methods. Utilization of R^3 technologies, such as AI™, not only serves as a remediation technique for hazardous materials, but also results in the production of viable products. When the value of these products are deducted from production costs (i.e., remediation), the end result is a reduced net project cost. As this applies to the E&P sector of the oil industry, there is a demonstrated need for all weather access roads, more efficient tank containment berms and dikes, paved loading and unloading areas, and other structures that will not only provide for more cost effective operations, but are more environmentally correct.

This study provides data on the environmental, engineering and economic aspects of utilizing $R^{3™}$methods, such as AI™, in the oilfield industry. It provides a starting point for producers to utilize their in-house personnel and equipment to recover resources and produce paving materials rather than managing their affected materials as a waste.

Report on the Study of Asphaltic Incorporation™ of Crude Oil Affected Soils
Redwood Tank Site
Tall Grass Prairie Area
Vicinity of Pawhuska, Oklahoma

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Introduction

This study was conducted by Raba Kistner Consultants, Inc. (RK) in conjunction with the International Petroleum Environmental Consortium and the University of Tulsa, Tulsa, Oklahoma. The subject of the study was to determine the environmental, engineering and economic feasibility of incorporating crude oil affected soils (COAS) from the historic Tall Grass Prairie Area in the Vicinity of Pawhuska, Oklahoma, as an ingredient in the production of non-hazardous, specified grades of asphalt paving materials for use on oil field and secondary roads.

Oil Fields and environmental quality has always been regarded as a quandary, perhaps best summed up by a statement at a recent Arkansas Oil and Gas Commission USEPA workshop. "The number one objective of oil producers is to get oil out of the ground." Only in the past twenty years have spill control and prevention technologies developed to the point where waste minimization and pollution prevention are accepted industry standard practices. This is not to say that producers are not concerned about the environment. Quite the contrary. In a majority of early Oklahoma and Texas oil field discoveries the landowners became the producers. An example would be the Electra, Texas field. The Ranch owners were looking for livestock water and to their dismay, albeit short-lived dismay, all they could find was oil. Today, seventy years later, the pump jacks and cattle continue to co-exist in an adapted environment. Land management and water are still a primary concern and they, as well as a majority of producers, have strong ties to their land and its resources.

Oil and water are as, if not more, important than they every have been. Past oilfield practices, that for 50 years or more were not regulated as they are now, have led to a number of large-scale environmental concerns, such as the situation in Tall Grass Prairie region of Oklahoma. The detrimental effects of historic crude oil and brine releases to surface and groundwater are now being realized and a major effort is underway to restore this area that originally to lead Native Americans and settlers to this unique Oklahoma environment.

Today's independent oil producers are facing a number of complex situations. Widely fluctuating oil prices, with more downs than ups, operation of stripper wells with production of one barrel a day, salt-water intrusion, high energy and operating costs and environmental regulations. Their job remains focused on getting oil out of the ground and trying to make a profit. Fixed costs, directly related to production, is first in their budgets. It is an unfortunate fact of life that environment is further down the list. But, where to get the dollars to restore a salt brine scar on their lease that were there 40 years before they took over. Or where to get the dollars to remediate an old reserve pit that may be older than the producer themselves, and all the other inherent environmental concerns they may not have caused, but are responsible for. The pump jack motor comes first. If there is any money left they may be able to dike up around the tank battery. Is this wrong? No, not necessarily. While we in the environmental remediation business cannot help our oil-producing clients with stabilizing oil prices, or reducing energy costs, or their depleting reserves, we can help with their second highest operating cost, which is environmental compliance.

It is up to us as an industry to provide cost effective, time efficient and environmentally correct solutions for our clients. When analyzing the cost of any environmental remediation project where can you save your client the most money? By reducing our hourly rate? This is not the answer. We have ever increasing fixed costs, the same as the producer has. Can we reduce equipment costs such as for a groundwater pump and treat system? While the units become more efficient every year, they also cost more money. What is the most often overlooked aspect of reducing environmental costs? It is the net project cost. What is a project's net cost?

Remediation net cost is the total combined costs, less any cost recovery credited to the producer. In some cases, reserve pit oil can be reclaimed for a few dollars, a little bit of pipe and steel may be salvaged, some drums of chemicals may be returned to the manufacturer for credit, but by and large, cost recovery for conventional remediation is a miniscule amount. Take land farming for example. You start with "dirty" dirt, spend some dollars piling it up and disking it around and you may wind up, eventually, with "clean" dirt. But its still dirt. You started with dirt, ended up with dirt that cost you some money. Regardless of your land farming costs, the gross cost is your net cost. There is no potential for cost recovery. Review all the other conventional and traditional oil field remediation methods. No matter how low a cost you can get your contractor to do them for, they are still non-recoverable costs.

A typical scenario may be standing oil around a tank battery, with inadequate containment dikes, along side a creek. The agency comes around tells the producer to "fix it". The "fix" is calling in a backhoe, digging a hole and "stabilizing" the oil with dirt. In some states, this is an agency acceptable practice. We see literally hundreds of these every year. The producers keep telling us their job is getting oil out of the ground. Okay, then why is it back on the ground and not sold? This is lost revenue. The dirt dike? Every time it rains or the vacuum truck runs over it, they lose containment, so they fix it again. This is lost revenue. Burying the spill? Even though in some cases agency approved, have you corrected the problem? The oil exemption of the Code of Federal Regulations Title 40 Part 261.4 (CFR40 261.4) is known and loved by all producers. Its still there, but so are the Oil Pollution Act (which does not exempt crude oil spills) the Clean Water Act (which does not exempt crude oil spills, the Endangered Species Act (which does not exempt crude oil spills), the Clean Air Act….shall we continue?

How can we reduce the net cost and long-term liability of the above scenario? By the use of Resource Recovery Remediation™ (R^3™). R^3™ is the regulatory and physical transformation of environmentally affected materials from a waste to a resource to a product. The on site use, off site sale or barter of these products provides cost recovery. Cost recovery reduces project net costs.

In the foregoing scenario the spilled oil is a resource. If feasible, recover the oil and sell it. If not feasible to reclaim it, why not bring in that same backhoe you'd have to have in the first place, load the oily soils on a truck, take it to a Producer operated facility and process it into asphalt. Haul the asphalt back to the lease, rebuild your liner and dike and be done with a whole series of problems. Cost comparison? How many times has such a spill occurred in the same dike? How many times have they "fixed" the dike? How much oily dirt have you buried on the lease? How much money have you spent over the years "fixing' the same problem. If the battery site was lined and diked with your own asphalt, you could recover the oil from the next leak and wouldn't get a letter from the agency saying "Congratulations you owe us $2,600 per day, everyday, until you get your dike fixed as you are in violation of the SPCC rules, the Clean Water Act, the Clean Air Act, the Endangered Species Act and every other Act we can think of, including the 3rd Act of Hamlet" (the part about "Alas poor Yourick, I knew him well…until he went out of the oil business".)

Oil producers are already in the Resource Recovery business. Accidental releases can become resources. Consider the advantages of managing your "wastes" as recyclable materials. There are a number of distinct regulatory advantages contained in CFR 40, Parts 261.2, 261.3, 261.6 and notably 266.20b concerning products produced for the general public's use.

Landfill disposal of oil field wastes is the most common of all remedial methods. In most cases its cheap, fast and easy. The problem is "fixed". Or is it? Currently in Texas the State is cleaning up a number of disposal sites that contained third generation wastes. They were wastes generated in the oil field, disposed of in a landfill that went bankrupt. Those disposal sites were cleaned up, the wastes hauled to another disposal site that met the same fate and now these sites are being cleaned up. Some of the wastes are 50 years old, but they are still wastes. Who's paying for this? The producers who disposed of the materials as wastes. These producers were traced by the disposal manifests and they have been named as Responsible Parties. It was the Producers waste to start with and legally still is. A short-term gain by a cheap easy fix, but a long term and very costly liability for the affected Responsible Party Producers. Not all landfills pose this problem. The point being, the Producers materials were managed as a waste. As such there is inherent long-term liability.

As previously stated, oil production and environmental concerns are a quandary. Waste minimization and pollution prevention programs are the best things to ever happen to oil field environments. But, when a release occurs they still have to be dealt with. This presentation attempts to provoke creativity from the environmental industry as well as the producers. A fact, not often voiced, but a fact all the same, is that the environmental concerns of in the oil fields are not the number one priority. A true concern, yes. But the concern is tempered by budgetary constraints. We ask that producers and industry alike start thinking "out of the box." What worked for Grandpa and Dad when they ran the field is not good enough now. Be creative. Innovate. Consider all the costs of your current environmental practices, and then develop ways to reduce your net costs. Convert your wastes to resources.

The following technical dissertation is intended as a starting point; call it "Resource Recovery 101". It discusses the three mandatory aspects of conversion of wastes to resources to products, which are Economics, Engineering and Environmental.

Background

The methodology used for this study is termed Asphaltic Incorporation™ (AI™). AI™ is a proven environmental remediation method that utilizes environmentally affected soils as a fine aggregate component in the production of cold processed asphalt paving materials. All specified grades of asphalt paving materials, whether hot mixed or cold mixed, have three major components:

- Coarse Aggregate (retained on a 2.36 mm (No. 8 sieve).
- Fine Aggregate (passing through a 2.36 mm (No. 8 sieve).
- Asphalt (a dark brown to black cementious material in which the predominating constituents are bitumens, which may occur in nature, or from petroleum processing).

Each project using AI™ is approached as site specific, unless it is known that end product usage, soil types and constituents of concern for a number of projects in a certain area are the same or quite similar, such as the Tall Grass Prairie. The first factor to be considered when using AI™ is the end use of the produced asphalt product. These products can range from non-load bearing, low permeability tank containment dike materials to all weather high traffic, heavy load bearing road pavements. Mix design formulation using, Asphalt Institute, State and Federal methods, is the process utilized to determine the ratio of various ingredients necessary to produce a product meeting end use requirements.

Determination of end use requirements may involve an engineering study to determine pavement thickness design. There are a number of pavement thickness design procedures one of the more adaptable procedures are those recommended by the Asphalt Institute in their publication No. MS-4 "The Asphalt Handbook". These design procedures are used to determine pavement thickness over asphaltic concrete base, emulsified asphalt base or untreated aggregate base or sub-base. The common steps in each design procedure involve selection of the type of input data which include sub-grade resilient modulus, expected traffic, surface and base material types and climatic conditions. Having determined design criteria, the next step is determination of design thickness, preparation of a "staged construction plan" (i.e., staging road construction in phases as budget permits for example preparation of road bed and drainage one year, then application of base the following year and finish pavement the year after), perform an economic analyses of the design and staging, then select the final design cross section. These are some of the steps required for "industry standard" pavement projects such as Interstate Highways, City Streets, etc. There are a number of differences between Interstates and Oilfield Lease Roads. However, adequate and economical design for pavements of all types are just as important as proper design of any engineering structure. An under-designed pavement will result in premature failure and cost more money for repairs and increase life cycle costs. Conversely a wasteful over-designed pavement or selection of materials that are not the most economical and adaptable for use is contrary to sound engineering practices and will unnecessarily deplete the project's budget.

As this relates to the oilfield, pavement design for these conditions present a number of challenges. The heavy axle loads of oil field transportation vehicles, the terrain in which the fields are located, climatic conditions, irregular maintenance intervals and cost. What a state highway department has to spend on design and product development is vastly different from independent oil production company. On one hand we state that thorough design is critical, on the other hand we recognize that the cost of design for each project may not be economically feasible.

By using a local engineering company's experience, local knowledge of other oil companies, state and county road crews and determining what the road will be required to withstand, may provide enough information to determine basic requirements. In other words, we encourage complete design procedures where possible. If not feasible, at least determine a "working estimate" for paving requirements based on local knowledge before proceeding with pavement mix designs for oil field roads.

Once it has been determined that a use exists for AI™ paving materials, the subject soil's environmental analyses are reviewed. The pre-incorporated constituent levels will be compared to the post-incorporated product samples to determine the degree of fixation, stabilization and encapsulation that has occurred by Asphaltic Incorporation™.

Engineering characteristics of the subject soils are determined by a series of tests including, but not limited to, moisture as received, density, gradation, and others. The characteristics of the affected soils provides an indication of the type of aggregate and other ingredients that may be required to enhance the soils physical properties.

The next step is preparation of laboratory mix designs. Various mix designs, incorporating different ingredient ratios are used to produce benchscale product samples. These samples are subjected to a number of engineering tests to determine their compliance with end use requirements. A number of States have developed specifications and test requirements for cold mixed asphalt paving materials. One of the more stringent and most often used procedural specification is the Texas Department of Transportation (TxDOT) specification No. 3157 "Cold Processed-Recycled Paving Materials". For States that do not have specific requirements for these types of materials, methods set forth in the Asphalt Institute's publication No. MS-14 "Asphalt Cold Mix Manual" are considered to be "Industry Standard." The engineering tests typically include:

- Compressive Strength – vertical load strength in an unconfined condition;
- Hveem Stability, or – resistance to deformation under vertical load;
- Marshall Stability – indication of lateral loading capabilities;
- Marshall Flow – measurement of materials "elastic" properties under load; and
- Density – (weight per cubic foot) – density of materials under compacted effort (indication of air void space).

The same samples that underwent engineering testing are then forwarded to a certified environmental laboratory. Samples are laboratory milled to a minus 10 micron size and subjected to Toxicity Characteristic Leaching Procedure (TCLP) testing in accordance with United States Environmental Protection Agency (USEPA) publication No. SW-846 protocol. TCLP testing is used to determine the leaching potential of the constituents of concern detected above regulatory agency action levels in the pre-incorporated soil samples.

Mix designs are then adjusted to produce the most cost effective blend of ingredients that will meet both engineering and environmental criteria. These designs are then utilized for field production.

During field production, samples are obtained from the cold mix asphalt plant discharge conveyor at 150-ton intervals, composited at a 10.1 ratio, and submitted to certified engineering and environmental laboratories to determine conformance to project criteria. Each 1,500 tons product lot is stockpiled and numbered and includes affected soil source, pre-incorporated soil analytical data, mix design formulation, aggregate source, asphalt emulsion source, batch number and suppliers laboratory data, both physical and environmental, dates produced and post-incorporation analytical data. No product is used on-site or transported off-site until lot number engineering and environmental data is received and determined to be in compliance with project requirements.

The AI™ process is considered complete when the product is applied for its intended use. Application documentation includes date(s) of lot number application, physical location of product placement and completed bill of lading.

As AI™ applies to the oilfield sector, there is a demonstrated need for all weather access roads, more efficient tank containment berms and dikes, paved loading and unloading areas and other structures that will not only provide for more cost effective operations, but are more environmentally correct.

This study approaches the subject of Oilfield Remediation from a different perspective. Instead of perpetuating the existing "spend and buy" cycle of most oilfield operations, this study attempts to provide a means to reduce remediation operation and maintenance net costs.

Often, the Environmental Department is "spending" to dispose of environmentally affected soils or other materials. Meanwhile down the hall, the Construction and Maintenance Department is busy "buying" commercial construction materials. In both cases it is money out the door. What if the Environmental Department met with Construction and Maintenance and determined their needs for asphalt paving materials. Using AI™, the Environmental Department would produce the required products and "sell" them to Construction and maintenance for a cost below commercial prices. The internal revenue gained by the "in house sale" of the product reduces the Environmental Department's net cost. The Construction and Maintenance Department reduces their project costs by paying less for the product. When applied, the product becomes a Capitol Improvement that is a depreciable asset. Depreciation provides for tax offsets, thereby improving corporate bottom line. Ending the "spend and buy" cycle produces a win-win-win situation.

Purpose and Scope of Work

The purpose of this study on the Tall Grass Prairie COAS was to determine whether the subject soils could be used as an ingredient in the production of specified grades of non-hazardous regulatory exempt, commercially viable asphalt paving materials. COAS for this study originated from an area known as the Redwood Tank

Site. A scope of work was developed to accomplish the purpose of this study. The scope of work is summarized by tasks as:

- 1.0 Pre-Incorporation Environmental Analyses of the COAS;
- 2.0 Pre-Incorporation Engineering Testing of the COAS;
- 3.0 Mix Design Formulation
- 4.0 Benchscale Product Sample Testing
  4.1 Engineering Tests
  4.2 Environmental Analyses
- 5.0 Cost Benefit Analyses

Following are discussions of the methods employed to complete the individual tasks and their results.

Task No. 1.0 – Pre-Incorporation Environmental Analyses of the COAS:

In order for AI™ to be considered a successful method for environmental soils remediation, it must be demonstrated that the constituents of concern have been fixated, stabilized and/or encapsulated in accordance with regulations contained in the Code of Federal Regulations Title 40, Part 266.20(b) (CFR 40 266.20(b)). The pre-incorporation analytical program determines the presence of constituents of concern (CoCs) and their concentration in the existing soils, which will be compared to analyses of the post-incorporated product samples.

Typically, projects similar to the Redwood Tank Site will have had site assessment and site characterization activities performed to determine the type and extent of suspected contamination. The analytical data generated by these activities could be utilized as pre-incorporation analyses as the data may be considered representative of site conditions by the regulatory agencies. For purposes of this study, the soil samples, as received, were analyzed by USEPA methods by a State-Certified environmental laboratory (San Antonio Testing Laboratory, San Antonio Texas) to determine the presence of CoCs and their concentrations in order to provide correlated data of pre- vs. post-incorporation constituent concentrations from specific soil samples.

Four 5-gallon plastic buckets of COAS, consisting to two from the most visually contaminated area of the Redwood Tank Site and two from the least visually contaminated area of the site. An effort was made to obtain samples that would be representative of site conditions as they may exist during remediation.

Upon receipt of the samples, RK's San Antonio, Texas laboratory personnel prepared composite aliquots from the most and least affected areas identified as "Sample No.1, 25% composite of bucket Nos. 1,2,3 and 4" to approximate site average constituent concentrations and another composited aliquot from the most affected area identified as "Sample No. 2 Composite of bucket Nos. 3 and 4 (worst case). These two composited aliquots were analyzed by the following EPA Methods in accordance with USEPA publication SW 846 requirements.

- RCRA Metals – Total Concentrations by EPA Methods 6010B, 7471 as applicable.
- RCRA Metals – Toxicity Characteristic Leaching Procedure (TCLP)
- Total Petroleum Hydrocarbon (TPH) – by EPA Method 418.1

- Reactivity – Cyanide and sulfide concentrations by EPA Method 7.3.3.2 and 7.3.4.2, respectively.
- Corrosivity – pH by EPA Method 150.1
- Ignitability – by EPA Method 1010
- Salts – by H_2O Leaching by EPA Method 6010B for Calcium, Potassium, Magnesium and Sodium, Method 353.3 for Nitrates and Method 4500 SM for Chlorides.
- TPH – by Texas 1006 Method for extended hydrocarbon chain range of Aliphatic and Aromatic constituents.
- Volatile Organic Compounds (VOCs) by EPA Method 8260B
- Semi-Volatile Organic Compounds (SVOCs) by EPA Method 8270C
- Pesticide Target Compounds by EPA Method 8081A
- Herbicide Target Compounds by EPA Method 8151A and
- Polychlorinated Biphenyls (PCBs) by EPA Method 8082.

These results indicate the pre-incorporated soils contained the following constituents in Sample #1 (site average) and Sample #2 (worst case), respectively, in the ranges shown below. All concentrations in mg/kg unless otherwise noted. CFR 40 Part 268 Subpart D, MCL's are shown in brackets where applicable

• Total Barium	142 to 148	(Not Applicable N/A)
• Total Cadmium	1.72 to 1.82	N/A
• Total Chromium	21.6 to 19.2	N/A
• Total Lead	20.8 to 19.2	N/A
• TCLP Barium	2.06 mg/l to 1.87 mg/l	(21 mg/l)
• TPH by 418.1	6,222 to 3,611	N/A
• Corrosivity (pH)	8.33 units to 8.42 units	(<2.0 or >12.5)
• Calcium	645 to 1050	N/A
• Potassium	55.3 to 187	N/A
• Magnesium	21.1 to 62.4	N/A
• Sodium	2,790 to 4,750	N/A
• Nitrates	<10 to <10	N/A
• Chlorides	10,870 to 11,810	N/A
• TPH by TX 1006 (Aliphatics)		
C12 to C16	145 to 59	N/A
C16 to C21	570 to 232	N/A
C21 to C35	1,694 to 646	N/A
• VOCs	Non Detect @ standard Method Detection Levels (MDL)	
• SVOCs	Non Detect (MDL)	
• Pesticides	Non Detect (MDL)	
• Herbicides	Non Detect (MDL)	
• PCBs	Non Detect (MDL)	

Based on the foregoing pre-incorporation analytical data, the subject COAS may be considered a "working average" of what may be expected on other sites in the Tall Grass Prairie area, i.e., heavy chain hydrocarbon indicating crude oil and salts associated with oil production brine.

Task No. 2.0 – Pre-Incorporation Engineering Testing of Affected Soils:

This series of tests is used to determine the engineering attributes or deficiencies of the subject soils. Data from this task is of primary importance to actual mix design formulation.

The pre-incorporation engineering test results "as received" follows:

- Moisture as received: Estimated 10.2%
- Density (wt. Per cubic foot) Estimated 97 lbs per cubic foot
- Plasticity Index Estimated 47
- Gradation (sieve size analyses) Soil appeared to be silty/clay with some Coarser gravel with 94.4 passing 1-1.4", 76% passing ½", 54% passing #4 and 17% passing #40.

Engineering test data indicated that while the COAS would not meet Specifications for total aggregate in their existing state, they could be amended to meet the gradation requirements by the addition of crushed limestone, caliche or other locally available aggregate. As the COAS at this site contained a relatively high clay content a pozzolonic reagent such as Fly Ash, Lime or Portland cement could be utilized to condition the soils in order to more adequately absorb asphalt emulsion. Based on previous project experience, the addition of pozzolons also tend to have a "neutralizing" or "buffering" effect on the brine salts.

Based on the engineering data, the subject COAS was deemed suitable for use as a fines component in the production of cold mixed asphalt paving materials.

Task No. 3.0 – Mix Design Formulation:

Mix design formulation was performed in accordance with Asphalt Institute Publication No. MS-14, TxDOT Specification 3157 for Cold Processed-Recycled Paving Materials, and other relevant requirements. It is noted that while the Oklahoma Dept. of Transportation (ODOT) does not yet have a specification for use of recyclable paving materials, there are specifications for asphalt stabilized base, and other similar paving products, that the end products of this study may be compared to, i.e., engineering properties will be the same, but the ingredients may differ. For the purpose of this study, Asphalt Institute standards were used.

A number of mix designs were formulated, each with varying percentages of ingredients. The two mixes that meet the majority of engineering requirements (i.e., TxDOT No. 3157, ASTM 4215 and Asphalt Institute) were selected to produce the benchscale product samples.

Trial Mix No. 1 was comprised of 40% soil, 45% crushed limestone, 10% Fly Ash, 2% Lime and 3% CSS-1h asphalt emulsion.

Trial Mix No. 4 was comprised of 35% soil, 46% crushed limestone, 12% Fly Ash, 4% Lime and 3% CSS-1h asphalt emulsion.

Task No. 4.0 – Benchscale Product Sample Testing:

Engineering Testing:

The designated Trial Mixes were compacted and formed into cylinders as required by the applicable strength and stability test procedures, in this case Compressive Strength, Density and Marshall Stability criteria.

The importance of this task cannot be understated. AI™ is a "Product First" technology. Unless the affected materials can be utilized as an ingredient in the production of non-hazardous specified grades of asphalt paving products, then the process is not cost effective. The value of the end product offsets remediation costs. If the product does not meet end use requirements, it has no value and cannot be managed as regulatory exempt recycled materials.

The main difference between specifications for commercial hot mix asphalts and cold mix asphalt, perhaps best explained in the Asphalt Institute publication MS-14, is that cold mix asphalt is designed to be a performance based product, in that the materials are designed to meet end use requirements. Hot mix, on the other hand, is produced from a standard "recipe". In layman's terms, hot mix is more of a "one size fits all" product. When one orders hot mix for a bicycle path, what is produced and delivered may be the same asphalt used for an interstate highway. Cold mix is designed to meet the demands of a specific project. Therefore, the ingredients may, and will likely vary from project to project. The project engineer determines the strength and stability required for the end use and the product is designed accordingly.

Cold mix specifically allows for the use of "roadbed" and "locally sourced materials" meaning that lower cost aggregate and other ingredients, not necessarily meeting the requirements for hot mix, may be used.

Marshall Stability and Marshall Flow are industry standard test methods often used to estimate a comparison between hot mix asphalt and cold mix asphalt in cases where the potential end user may be more conversant with a commercial hot mix than field produced cold mix asphalt.

The Marshall Stability test is designed to determine load bearing stability and resistance to torsional shear and is a test used in many areas in place of Hveem Stability testing.

Marshall Flow is an integral part of Marshall Stability testing and is used to determine the lateral deflection of a material at the point of cracking or deformation. Asphalt paving materials must have a certain amount of flow designed into the product to withstand deflection caused by traffic and climatic conditions.

The Asphalt Institute publication No. MS-22 "Construction of Hot Mix Asphalt Pavements" lists the following Marshall Stability and Flow criteria:

- Light traffic surface and base – minimum 750 lbs with a Flow between 8 to 18;
- Medium traffic surface and base – 1200 lbs with a Flow between 8 to 16; and
- Heavy traffic surface and base – 1800 lbs with a Flow between 8 to 14.

Benchscale test results for Marshall Stability for Trial Mix No. 1 was an average of 2358 lbs., and a Flow of 10. For Trial Mix No. 4 the average Marshall Stability was 2358 and a Flow of 7.

Comparing these cold mixed asphalt results to the Marshall stability and Flow requirements of hot mixed asphalt, indications are that both Trial Mix No. 1 and No. 4 exceed the requirements for Heavy traffic, which incidentally are the requirements for Interstate Highways and Airport Runways. The Flow for Trial Mix No.1 is within the tolerances of 8 to 14, being 10. Trail Mix No. 4 Flow was 1 point less than the low tolerance indicating a slightly “harder” product than required.

These above average results indicated that the mix designs could be adjusted to incorporate more soil and less commercial ingredients which will reduce production costs.

The two selected trial mixes were also tested for compressive strength. Compressive strength is a test designed to determine a material’s ability to withstand the pressures of compression brought about by repeated traffic. The Asphalt Institute does not provide a standard for compressive strength, however TxDOT Specification 3157 requires a compressive strength of 35psi for secondary roads and 50psi for primary roads (major arterial roads and highways).

Benchscale product sample engineering tests indicate an average compressive strength for Trail Mix No. 1 of 135psi and for Trail Mix No.4 of 139 psi. These results are also well over those required for standard heavy traffic usage and also indicate a revision of ingredient ratios could be accomplished.

Density testing is an important indicator of the environmental viability of AI™ paving materials from an engineering perspective. The weight per cubic foot of AI™ paving materials is an indicator of a dense material equating to minimal void space. Minimal void space translates to low permeability. Low permeability materials retard leachability and moisture infiltration. Moisture infiltration is an important design criteria as the less moisture infiltration the less internal damage to the product matrix caused by climatic freeze thaw cycles.

The average density of Trial Mix No.1 was 129 pounds per cubic foot (pcf) and for Trial Mix No. 4 was 131.8 pcf. This compares very favorably with the Asphalt Institutes average of 135 pcf for most densely graded (heavy) hot mix asphalt.

While all the engineering tests may exceed their various industrial standard requirements, re-design of ingredient ratios is not normally performed until receipt and review of benchscale product sample environmental analyses.

Environmental Analyses:

Environmental analyses were conducted in accordance with CFR 40 266.20(b) referencing the MCLs of CFR 40 Part 268 Sub-Part D. The analyses were performed on the same samples that had undergone engineering testing per Task No. 4.0 A. The objective of these analyses was to determine the presence of any of the regulated constituents at levels exceeding the above referenced MCLs.

Results indicated non-detectable TCLP concentrations at laboratory standard method detection levels for Volatile Organic Target Compound, Semi-Volatile Organic Target Compounds and the 8 RCRA Metals with the exception of barium which was reported in concentrations of 1.42 mg/l in Trial Mix No. 1 and 2.85 mg/l in Trial Mix No. 4. These reported concentrations are well below the level for barium established by CFR40 Part 268 Subpart D, which is 21 mg/l.

Indications are that the benchscale product samples comply with Federal regulations regarding the use of recyclable materials applied to the land and are therefore regulatory exempt in accordance with CFR 40 Part 266.20(b).

Task No. 5.0 – Cost Benefit Analysis:

Having determined the mix design percentages of ingredients and achieved the engineering and environmental standards for the benchscale samples, production costs can then be estimated.

The following benefit analysis (CBA) compares AI™ production costs to a load, haul and dispose scenario. The value of the AI™ product, based on comparable locally purchased products is factored in to arrive at a net project cost.

Cost Benefit Analysis

Asphaltic Incorporation™ of Crude Oil Affected Soils vs Load, Transport, Dispose and Purchase of Commercial Paving Materials

Disposal and Materials Purchase		Asphaltic Incorporation™	
Disposal		Resource Recovery	
Transportation	Avg. $9.00/ton	Transportation	Avg. $4.00/ton
Disposal Fee	Avg. $24.00/ton	Acceptance Fee	Avg.$12.00/ton
Materials Purchase		AI™ Production	
Hot Mix Cold Laid		Production Cost	
Asphalt Base	Avg.$32.00/ton	(Net less acceptance fee)	$15.00/ton
Transportation	Avg. $ 5.00/ton	Transportation	Avg.$4.00/ton
Total Combined Disposal and Materials Purchase Cost	$70.00	Total Combined AI™ Costs	$35.00

These costs can vary considerably as discussed in Table 1. However for the scenario of operating a producer owned facility(s) in close proximity of the COAS generating sites, these costs are reliable enough to provide an accurate cost comparison for not only disposal, but other remedial methods as well.

Conclusions

In the oilfield, there is an ever present need for all weather, heavy load roads. However, to construct a road network using the same specifications for sub grade preparation and compaction, a flex base layer, with an asphalt base and wear surface required for standard highways may be cost prohibitive.

The current alternative is to spread gravel or other aggregate and hope for the best. This results in weather related down time and high maintenance costs. These maintenance costs are somewhat elusive and need to be accounted for on an all-inclusive basis to arrive at a true cost. A truckload of rock and a couple of hours of road grader time do not appear to be that great of expenditure. But, add up all these incidental costs, rig down time for mud or washouts, repairs on the pumper or vacuum truck, tractor time winching rigs in and out; it all adds up to be a considerable expense.

Field produced cold mixed asphalt can provide strength and stabilities designed to be the same as hot mix, for less than off site purchase of commercial asphalt paving materials. The affected soils, which would otherwise cost money to dispose of, can become the required fines component in the production of specified grades of asphalt paving products. When applied, these products can become capital improvements. Capital improvements may be depreciable assets that may provide tax offset. Other long-term benefits include reduced maintenance cost and related down time as the producer may have all weather roads. Maintenance costs may be reduced by up to 75%, environmental issues of spreading oil on the roads, erosion, dust and a host of others may be resolved, accident rates can decrease due to better roads, the list of benefits goes on and on.

Another scenario for the use of recycled paving materials is rural counties that may be under funded. It has been estimated that in Oklahoma, as well as Texas and other parts of the southwest, up to 60% of a Counties annual budget is spent on road maintenance. The maintenance interval to pull up the road shoulders, re-crown the road, level and reshape borrow ditches is normally once a year. What if this maintenance interval was decreased from once a year to once every four years by using low cost asphalt paving materials? The positive impact on an already strapped county budget becomes very apparent.

There is an opportunity for public/private sector partnering (i.e., counties and the oil producers). Most counties have the equipment necessary for Mixed-in-Place AI™ production. The oil producers have the affected soil. A barter agreement, which is being done in Texas now, is entered into whereby the Producer pays for the asphalt emulsion and reagent (if needed). The county supplies the equipment to produce and apply the product. The end product is split 50/50. The county applies the producer’s share and they get half of the product for their own use. AI™ can truly be a win-win situation.

Table 1 Cost Benefit Analysis Asphaltic Incorporation™ of Crude Oil Affected Soils vs Load, Transport, Dispose and Purchase of Commercial Paving Materials

Disposal and Materials Purchase		**Asphaltic Incorporation™**	
Disposal		Resource Recovery	
Transportation [a]	Avg. $9.00/ton	Transportation[c]	Avg. $4.00/ton
Disposal Fee[b]	Avg. $24.00/ton	Acceptance Fee[d]	Avg.$12.00/ton
Materials Purchase		AI™ Production	
Hot Mix Cold Laid		Production Cost [g]	
Asphalt Base[e]	Avg.$32.00/ton	(Net less acceptance fee)	$15.00/ton
Transportation[f]	Avg. $ 5.00/ton	Transportation [h]	Avg.$4.00/ton
Total Combined Disposal and Materials Purchase Cost	$70.00	Total Combined AI™ Costs	$35.00
		Net Estimated Cost Benefit	$35.00

(a) Transportation estimates varied up to $4.50 per mile for longer hauls, to $50.00 per truckload for short hauls of ten miles or less. The average was approximately $4.00 per mile and a 50-mile haul. $50.00 x $4.00 = $200.00 per load ÷ 20 tons = $10.00, revised down to $9.00 to be conservative.
(b) Information obtained during the course of this study indicated a very wide disparity in disposal costs and more importantly, acceptance criteria. Costs ranged from $40.00 per ton to a fully permitted nationwide corporation facility, to $6.00 per ton for a privately owned solid waste landfill, who proposed to use the soils as "daily cover" with no acceptance criteria.
(c) Transportation is theorized as being to an oil producing area facility or if quantities warranted, on-site production. The $4.00 average was conservatively high.
(d) The acceptance fee is designed to offset operation costs of a Producer owned and operated facility.
(e) This is an average of 4 hot mix asphalt plants within viable transportation radius.
(f) This is an average quoted by the Hot Mix Asphalt Plants.
(g) Cost estimated from Trial Mix Design Nos. 1 and 4 ingredient cost, production equipment cost, engineering and environmental analyses less the Acceptance Fee.
(h) Estimated to be the same as (e) above.