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Remedial Action Plan for a petroleum hydrocarbon release

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REMEDIAL ACTION PLAN
FOR A PETROLEUM HYDROCARBON RELEASE

Marty E. Murrietta
May 2, 1998
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Executive Summary

This Remediation Action Plan (RAP) presents the methods and results of feasibility testing, the screening and selection of remedial options, preliminary conceptual design, methods, permitting requirements, recommendations and cleanup goals for on- and off-site remediation of petroleum hydrocarbon impacted soil and groundwater at an undisclosed site in Laughlin, Nevada. This site is an active convenience store and former retail fueling station. Plans are being made for the demolition of the fueling station and construction of a Factory Outlet Mall on the former refueling station site and surrounding properties to the south, west, and northwest. Remediation activities cannot significantly interfere with the demolition and construction plans for the mall facility. A total of three underground storage tanks (USTs) have been removed along with approximately 453 tons of hydrocarbon contaminated soil which was transported to Las Vegas Paving Corporation for thermal treatment. A total of 24 exploratory soil borings were advanced during the on-site and off-site assessment. Nine soil borings were advanced on- and off-site, of which five were converted to groundwater monitoring wells.

Before the remedial action plan can be developed an evaluation of several activities must be assessed, such as, subsurface conditions in the vicinity of the removed USTs and feasibility testing, which is ultimately the primary basis in deciding the type of abatement which will take place.

This RAP discusses and evaluates the feasibility of various proposed soil and groundwater remediation alternatives. The selected remedial system incorporates soil ventilation, groundwater air sparging, and air emissions controls. Groundwater treatment will be by in-situ air sparging to enhance biodegradation and volatilization of dissolved

contaminants. Volatile subsurface contaminants will be recovered through soil ventilation. Air emissions will be controlled by a thermal/catalytic oxidizer or carbon adsorption units as determined by concentrations of volatile organic compounds (VOCs) and cost factors. This remedial system has been selected based on site geology, utilities and structure, hydrogeologic conditions, contaminant transport, planned construction activities and economic considerations. Detailed discussion of the selection criteria and comparisons of alternatives will also be discussed in this report.

This research report is factual and as detailed as would be used by any remediation company to be submitted to the Nevada Petroleum Fund for evaluating the technical and economical considerations.

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1.0 INTRODUCTORY

1.1 Background

The former refueling station contained two 8,000-gallon bare steel underground storage tanks (UST) installed in 1978, and one 8,000 gallon fiberglass UST installed in 1987. All the UST's apparently contained gasoline. During tank removal activities, performed approximately one year ago, hydrocarbon odors were observed in the soils surrounding the UST's. Heavy staining observed near the southern end of the southeastern UST suggested a leak in the associated product pump. Due to site restrictions, (unstable sands and proximity to the sidewalk and store building) impacted soils were not completely excavated. After removal of approximately four hundred and fifty three tons of accessible contaminated soils, the UST area was backfilled and compacted (Stewart, 1997).

Site assessment activities conducted by STEWART ENVIRONMENTAL between April and July have been documented. An Additional Site Assessment Report has also been completed and does include advancing and sampling of nine soil borings and twenty-four probe locations, and installation and sampling of five groundwater monitoring wells. Information collected during the site assessment indicated that petroleum hydrocarbon impacted soil and groundwater was present beneath the site and had migrated off-site to the southeast. Site assessment results are discussed in detail in Section 3.0.

1.2 OBJECTIVE

The purpose of this remedial action plan was to screen and select feasible remedial options, develop a preliminary conceptual design, and formulate

methodology, permitting requirements, and clean-up goals for the gasoline release at the former fueling station.

1.3 PURPOSE AND NEED FOR ACTION

The release of gasoline fuel from an underground storage tank (UST) is a potential hazard to the surrounding environment. Immediate remediation would abate or eliminate any further potential contamination of the area. Potential impacts would be to soil, air, and groundwater due to the release of the volatile organic compounds (VOCs). The need for quick action will decrease the probability of the contaminant from seeping deeper into the soil and migrating toward the water table and the surrounding properties. The appropriate regulatory agencies were promptly notified. Pumping the UST's dry permitted some of the gasoline fuel to flow back into the UST. An uncertain quantity was absorbed into the surrounding soil. The natural surrounding sand, silt, gravel, and feldspar worked as a nature sponge in absorbing some of the gasoline.

2.0 SITE ASSESSMENT SUMMARY

2.1 GEOLOGY

2.1.1 Regional Geology

Laughlin, Nevada is situated along the western bank of the Colorado River approximately four to five miles down river from Davis Dam and Lake Mojave. The area is the Nevada, Arizona, and California tri-state region situated near the southern tip of Clark County, Nevada. Laughlin lies upon accumulations of alluvial valley fill of the Colorado River. The alluvium is derived locally from predominantly Precambrian bedrock and minor Tertiary volcanics exposed to the west in the Newberry Mountains and from various bedrock materials derived from sediment transport along the Colorado River (Nevada Bureau of Mines and Geology, 1964).

Precambrian and minor Tertiary volcanic bedrock is exposed approximately one mile to the north near the Nevada State Highway 163 and predominantly Precambrian bedrock is exposed in the Newberry Mountains approximately three to four miles to the west.

2.1.2 Local Geology

Based on site observations during site assessment activities, subsurface soil can be divided into a western alluvial fan sequence and an eastern river sequence. The alluvial fan sequence consists of deposits of well-graded sands, silty sands and gravels. These materials are general dense and compact deposits consisting of relatively immature, angular to sub-

angular clasts of feldspar, quartz and granitic rock fragments. The alluvial fan deposits are generally located on the western half of the former refueling station property (Stewart, 1997).

The river sequence consists of interbedded sand and clay units with minor gravel lenses locally. The sand units are generally fine-graded, poorly graded, mature quartz sand. A clay unit is present at depths of approximately 16 to 27 feet below ground surface (bgs). Fine grained, flowing sands are present below the water table (Nevada Bureau of Mines and Geology, 1964).

2.2 HYDROGEOLOGY

2.2.1 Regional Hydrology

Laughlin lies near the toe of a large alluvial fan originating along the eastern slopes of the southern extension of the Newberry Mountains and terminating at the Colorado River. The intake for this water supply is located upstream between Laughlin and the Davis Dam.

2.2.2 Local Hydrology

The depth to groundwater beneath the site is approximately 25 feet bgs. Groundwater at the site appears to be flowing to the southeast with a gradient of approximately 0.007 to 0.022 feet vertical per foot horizontal (ft/ft) (Geology and Mineral Deposits of Clark County, 1964).

Surface drainage would leave the site to the east, flow along South, and enter a storm sewer drain and eventually the Colorado River. The Colorado River is located approximately 1,000 feet to the east of the site.

2.3 CLIMATE

Laughlin has an arid to semi-arid climate with an average annual precipitation of 4.19 inches (Laughlin Chamber of Commerce, 1997). Temperatures range between 40° F to 70° F in the winter with maximum temperatures of 120° F or more in the summer (Laughlin Chamber of Commerce, 1997).

Comment [MEM1]:

2.4 SOIL ANALYTICAL RESULTS

A total of 48 soil samples were collected and analyzed during the site assessment activities including four UST compliance soil samples, 22 soil boring samples, and 22 probe samples. Ten of the samples were reported to contain total petroleum hydrocarbons (TPH) exceeding the NDEP action level of 100 milligrams per kilograms (mg/kg). Reported TPH concentrations ranging from 110 to 3,800 mg/kg. Soil samples above the NDEP action levels for TPH were collected from soil borings MW-2, MW-3, B-1, B-2, and B-4 in the immediate vicinity and approximately 40 to 50 feet to the south and southwest of the former Ousts. Petroleum hydrocarbon impacted soils are 15 to 20 feet thick in the immediate vicinity of the former USTs and thins to five to 10 feet thick near the edges of the soil plume (Stewart, 1997).

2.5 GROUNDWATER ANALYTICAL RESULTS

A total of 31 groundwater samples were collected and analyzed during site assessment activities including 23 probes samples and eight groundwater monitoring well samples. The groundwater samples were analyzed for TPH and volatile aromatic compounds; benzene, toluene, ethylbenzene, and xylenes (BTEX). Petroleum hydrocarbon compounds were detected in six of the probe

samples with reported TPH concentrations ranging from 0.44 to 16.0 milligrams per liter (mg/L) and benzene concentrations ranging from 3.0 to 1,500 micrograms per liter (ug/L). Samples collected from the groundwater monitoring wells were reported to be below the laboratory detection limit for TPH and BTEX in two upgradient and one downgradient wells. Groundwater samples collected from monitoring wells MW-2 and MW-3 located in the immediate vicinity of the former USTs were reported to contain TPH concentrations up to 56 mg/L, benzene concentrations up to 2,700 ug/L and total xylene concentrations up to 13,000 ug/L. Reported BTEX concentrations for both MW-2 and MW-3 are both above the NDEP action levels allowed for each BTEX compound. The groundwater plume appears to be centered on the former USTs. Groundwater impact extends upgradient approximately 80 feet, possibly as a result of vadose zone transport to the northwest along a low permeability clay horizon. The groundwater benzene plume is approximately 90 feet wide and 170 feet long and trends to the southeast (Stewart, 1997).

2.6 SITE UTILITIES AND STRUCTURES

There are numerous subsurface utilities and above ground structures near the petroleum hydrocarbon impacted areas of the former refueling station. Below ground utilities enter the property near the northern boundary and a sanitary sewer line is located south of the market building. There are underground utilities underlying the street to the east and a no cut policy is in place for this main thoroughfare. An outlet mall building is located to the west of the release site.

The on-site subsurface utilities, site structure, and future construction activities play a role in evaluating remedial alternatives and the placement of soil ventilation and groundwater remediation wells.

3.0 PUBLIC IMPACT

- The depth of the groundwater:

There have been many measurements collected for the elevation of the on-site groundwater monitoring wells over the last year. The average depth to groundwater is approximately 22 feet below ground surface (hydrocarbons have been detected, reaching the groundwater) although, the probability of contaminating the drinking water supply is very minimal, because the drinking water supply is approximately five miles up stream from the contaminated site, near Davis Dam.

- The distance to irrigation or drinking water well:

The distance to the nearest irrigation or drinking water well is approximately five miles up stream from the contaminated site, near Davis Dam.

- The type of soil:

Based on site observations during site assessment activities, subsurface soils can be divided into a western alluvial fan sequence consists of deposits of well-graded sands, silty sands, and gravels. These materials are generally dense and compact deposits consisting of relatively immature, angular to sub-angular clasts of feldspar, quartz, and granitic rock fragments. The alluvial fan deposits are generally located on the western half of the property.

The river sequence consists of interbedded sand and clay units with minor gravel lenses locally. The sand units are generally fine-grained, poorly graded, and mature quartz sand. A clay unit is present at depths of approximately 16 to 27 feet below ground surface (bgs). Fine grained, flowing sands are present below the water table.

- The annual precipitation:

Laughlin, Nevada has an arid climate with an average annual precipitation of 4.16 inches (Laughlin Chamber of Commerce, 1997).

- The type of regulated substance released:

Gasoline fuel.

- The extent of contamination:

The soil borings revealed hydrocarbon contamination to a depth of up to 25 feet bgs. The soil contamination ranges from a depth of approximately 15 to 25 feet bgs. The radius of the contamination is approximately 150.

- The present and potential land use:

The use above the former UST area is currently access driveway, parking lot, and landscaped area. Asphaltic concrete covers the area directly above the impacted soil area to reduce the potential for storm run-off and precipitation to infiltrate and leach through the impacted soil. The land use down gradient and to the east is a Casino. The land use west of the site is an outlet mall. There are no anticipated changes in the land use in the vicinity of the old USTs.

- The preferred routes of migration:

The preferred route of migration would be through the subsurface soil, such as sand lenses and silt lenses. The risk of the gasoline product migrating further in depth is not likely due to the natural clay layer at about 20 feet acting as a barrier.

- The location of structures or impediments:

There is nothing in the very near vicinity that may be at risk during remediation of the site. Casino Drive is located adjacent to the site and the outlet mall is on the other

side of the remediation site, in which neither site will inhibit or stop the process of remediation.

- The potential for a hazard related to fire, vapor or explosion:

The potential for fire or any type of explosion due the gasoline leakage is very minimal. The majority of the contaminant has been removed from the site and is covered with asphaltic concrete and landscape at the edges of the contamination. With the contamination completely being covered there is no direct access to the surface (Stewart, 1997).

4.0 Feasibility Testing

The purpose of the feasibility testing described below was to establish site-specific parameters necessary for the remedial option selection, the development of the conceptual remedial system, and detailed design. These parameters are needed to establish the number of wells required, capacity requirements for system components, permitting and cost estimate refinements.

4.1 Soil Ventilation Testing

The testing for soil ventilation included the installation of soil ventilation wells, vapor probes, and piezometers, a pilot test of the soil ventilation wells to evaluate the effective radius of influence soil remediation. Based on these results, vacuum blower capacities and the need for additional soil ventilation wells was evaluated.

4.1.1 Soil Ventilation Well Construction

Two soil ventilation wells (SVWs) were installed in the vicinity of the former USTs. The soil borings were advanced with a ten-inch diameter drill bit. During drilling, an environmental geologist classified the soils according the Unified Soil Classification System (USCS) logged the boreholes and collected soil samples. The soil ventilation wells were constructed to provide extraction points of soil ventilation feasibility tests and are designed to serve as future soil remediation wells (Stewart, 1997).

The SVWs were constructed of four-inch diameter, flush threaded, PVC casing and a factory slotted screen. A filter pack of Monterey sand was carefully placed

around the annular space between the well screen and the wall of the soil boring to a depth approximately 1.5 feet above the top of the screened interval. A bentonite seal with an approximate thickness of at least two-feet was placed on the top of the filter pack to provide an airtight sanitary seal. A neat cement grout slurry was then placed in the annulus between the wall of the soil boring and the well casing from the top of the bentonite seal to near surface grade. A flush mounted, traffic rated, well box was installed slightly above local grade to establish positive surface drainage away from the well box. The SVW's were capped with water tight, locking cap and padlocked to discourage unauthorized access (Stewart, 1997).

4.1.2 Vapor Probe Construction

A total of four vapor probes were installed in the immediate vicinity of the former USTs using a drive point hydraulic ram and jack hammer. The probes were installed by advancing an expendable anchor point and drive rods to the desired depth. A 21 inch long, doublewoven, stainless steel wire micro-screen with 0.0057-inch pore openings were attached to polyethylene tubing and inserted down into the drive rods and secured to the anchor point. A filter pack of glass beads was placed around the annular space between the micro-screen and the probe bore hole while extracting the drive rods to a point approximately six inches above the micro-screen. A bentonite seal was placed above the filter pack to near the surface grade. The probe construction was completed using a three inch threaded PVC, mini-well box cemented in place. The vapor probes were installed to provide pressure/vacuum-monitoring points at varying distances from

the testing wells for evaluation of radial influence. These probes were also designed to be used as monitoring points during soil remediation (Bouwer, 1976).

4.1.3 Piezometer Construction

A total of three piezometers were installed in the vicinity of the former USTs using a drive point hydraulic ram and jack hammer. The piezometers were constructed of three-foot lengths steel pipe and 0.20-inch vertically slotted screen. The pipe was assembled using threaded unions and Telfon tape. The piezometers had welded steel tips and were driven into the subsurface to total depth. Pilot holes were advanced prior to installation of the piezometer to facilitate installation. The annulus of the piezometers was sealed with bentonite and finished at ground surface with a steel or PVC threaded cap. The piezometers were installed to monitor the effects on groundwater during pressure tests conducted on MW-2 and MW-3. The piezometers were also designed to serve as monitoring points during groundwater remediation (Bouwer, 1989).

4.1.4 Positive Pressure Test

Positive pressure tests were performed on the two existing impacted groundwater monitoring wells, monitoring well one and two, to evaluate their use as potential vapor recovery wells. The tests were performed by introducing pressurized air into the groundwater monitoring wells using a secured well cap outfitted to receive an air hose from a portable air compressor. Pressurized air was introduced to each well and the pressure was allowed to stabilize. Pressure readings were recorded at predetermined times in monitoring probes distributed around the testing well. Water levels were also recorded in surrounding

piezometers, during the positive pressure tests. The tests were conducted for a period of 30 minutes.

4.1.5 Negative Pressure Tests

Negative pressure tests were performed on two newly installed soil ventilation wells to evaluate soil air permeability and radius of influence for soil ventilation feasibility evaluations. A vacuum was applied to soil ventilation well (SVW) one and two using a negative pressure blower. The blower intake was connected to the well head using PVC pipe and fittings. Vacuum readings were monitored at surrounding probe points on a pre-determined timed interval.

An air sample was collected in two tedlar bags from the sample port on the blower exhaust at the end of testing on SVW-1. This sample was shipped to the analytical laboratory under chain-of-custody procedures for analysis of TPH, CO₂, and O₂ (Stewart, 1997).

4.2 Aquifer Testing

The testing was performed to evaluate aquifer parameters included slug tests, sieve analyses of aquifer materials and falling head permeability tests. Slug tests were conducted on five monitoring wells. Hydraulic conductivities for the river sequence ranged between 4.2 and 4.9 ft/day. The sieve analysis of the alluvial fan sequence indicates well-graded material with grain size distributions of 12% gravel, 71.6% sand, and 16.2% silts and clays, with the sand fraction being well graded with decreasing proportions of finer sand fraction. The sieve analysis of the river sequence aquifer reports poorly graded fine-grained sands ranging from 66.4 to 91.6% and silts and clay fractions of 8.4 to 33.6%.

Falling head permeability tests were performed on four samples of aquifer material to determine vertical permeability (Bouwer, H., 1989).

4.3 Biodegradation Testing

Three soil samples impacted with petroleum were sent to A&L Western Laboratories, Inc. for analysis of micronutrients including; organic matter, nitrogen, phosphorus, magnesium, calcium, sodium and pH, and total aerobic bacterial plate counts. This data was used to evaluate the presence of soil bacteria and micronutrients necessary for biodegradation. Ideal conditions for biodegradation includes a carbon to nitrogen to phosphorous ratio of 100:10:2. Based on average TPH concentrations of 1,323 mg/kg in impacted soils, the expected micronutrient requirements for complete biodegradation are 110 ppm nitrogen and 22 ppm phosphorous. The soil analysis provided by A&L Western Laboratories indicated low concentrations of nitrogen (3.0 to 4.0 ppm) and phosphorous (7.0 to 31 ppm) available for biodegradation. This suggests a need to supplement the nutrients supply during remediation if biodegradation is expected to play an important role in site remediation of impacted soils.

The results of the aerobic plate counts for the three-petroleum hydrocarbon impacted soil samples report plate counts of between 2,200 and 3,300 colony forming units per gram (CFU/g). These results are considerably lower than the 1.0×10^6 CFU/g or greater counts generally considered of an active and viable soil bacteria population in petroleum impacted soils. However, these low plate counts may be accounted for as the results of low soil gas oxygen and lack of micronutrients, particularly nitrogen and phosphorous (Stewart, 1997).

An air sample collected from the blower exhaust of soil ventilation test SVW-1 was analyzed for carbon dioxide and oxygen content. The results of this analysis reported a CO₂ concentration of 16% by volume (vol. %) and an O₂ concentration of 2.1 vol. %. The high CO₂ content and low O₂ content indicates that aerobic biodegradation of the petroleum hydrocarbons has taken place. Much of the soil gas O₂ has been consumed, and the rate of aerobic biodegradation is not likely to continue without an augmented oxygen supply.

4.4 Data Interpretation

4.4.1 Soil Contaminant Mass Estimate

From previous site assessment reports, the contaminated soil volume was estimated to be 2,350 cubic yards consisting of a circular surface area of 5,280 sq.ft. and an average thickness of 12 feet. Using a soil density conversion of 1.3 tons per cubic yard (tons/yd³), this volume equates to 3,055 tons. In order to calculate the TPH in this soil mass, the TPH concentrations exceeding NDEP action levels of 100 mg/kg averaged 1,323 mg/kg TPH. This average concentration multiplied by 3,055 tons equals 4.0 tons of TPH in the soil mass.

4.4.2 Soil Air Permeability Calculations

In order to better understand the soil characteristics of the site, the soil air permeability was calculated from the feasibility test.

$$k = \frac{Q_v}{4 \text{ @ } m_A}$$

Where: Q = volumetric vapor flow rate from the extraction well

ν = Viscosity of air (1.8×10^{-4} gm/cm. sec.)

m = Stratum thickness

A = Slope of pressure vs. \ln (time)

π = $\pi = 3.1416$

The soil permeabilities varied between 58 and 427 darcies

(1 darcy = $0.987 (\text{cm}^2)$) across the site. The results indicated that the northern portion of the site is more permeable than the southern portion. The soil permeabilities on the southern portion of the site measured between 20 and 290 darcies across the site. These permeabilities are in the range of values expected for medium to coarse-grained sands (Stewart, 1997).

4.4.3 Radius of Influence Evaluation

An estimate of the radius of influence was calculated by plotting vacuum vs. radial distance and extrapolating the radial distance at which the measured vacuum was 1% of the applied vacuum. The radius of influence corresponds to 1% of the applied vacuum. By interpolation of the exponential equation, the radii of influence are 45.5, 21, and 19.5 feet deep for the extraction wells, one and two and a second test on well two.

5.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section presents a discussion of applicable response actions and associated technologies with a summary of feasible remedial alternatives considered for this site. Those response actions generally applicable for TPH contaminated soil and dissolved petroleum product impacted groundwater are listed in Section 5.3. The technologies that pass the screening process are assembled into remedial alternatives and discussed in Section 5.4 and 5.5.

The screening process and selection of the recommended remedial alternative for TPH impacted soil and groundwater considered several critical site-specific factors including:

- Convenience Market Requirements - Because this is an active convenience store and future construction site of a Factory Outlet Mall, there can be no major disruptions to access or planned construction activities at the facility. Potential economic impact of prolonged remediation and the risks associated with unremediated on and off the site contamination need to be considered.
- Site Specific Factors – Geology – The subsurface soils are characterized as predominantly fine-grained sediments ranging from clays to poorly-grained sands with minor gravel lenses. Two distinct sequences are present beneath the site; a western alluvial fan sequence of compact, immature, silty sands and gravels, and an eastern river sequence consisting of interbedded clays and poorly graded, mature, quartz sands. Flowing sands are present within the saturated zone.

- Site Specific Factors – Hydrogeology – Groundwater was encountered at approximately 25 feet below ground surface. Dissolved gasoline compounds impact groundwater. The groundwater plume is a circular area approximately 90 feet wide by 170 feet long extended across the near by highway. The area of the groundwater plume is approximately 3,825 square feet. The affected aquifer appears to be approximately 15 to 20 feet thick below the former USTs, thinning to a thin surface layer across the highway. The groundwater flow direction appears to be to the east-southeast.
- Regulatory Requirements – The NDEP, CCHD, and other state and local agencies established requirements for soil and groundwater remediation and treated discharge are outlined in Section 5.1. These requirements eliminate alternatives such as No Action or Containment.
- Costs and Engineering Requirements – Several key requirements for the convenient store in this area include implementation, remedial action, time frame, effectiveness, cost, future construction activities, and approval from the Nevada Petroleum Fund. The recommended alternative should have should have demonstrated effectiveness and be readily implemented at this site. Cost effectiveness is a key criteria, and should include operation and maintenance costs. These criteria eliminate the alternative of additional soil excavation and disposal, since it is not cost effective nor technically feasible considering the site restrictions, the on-site utilities and structures, active retail site operations, and the presence of unstable sands.

5.1 SITE SPECIFIC REMEDIATION OBJECTIVE

Remediation objectives are site specific and depend upon parameters such as the type of contaminant, land use, soil type, water use, proximity of water supply wells, access, utilities, volume of impacted soil, depth to groundwater, groundwater quality, groundwater flow direction and gradient, type and location of receptors, and routes of exposure.

In addition to reviewing site specific parameters, current NDEP guidelines and regulations, which require a remedial objective of 100 mg/kg of TPH for impacted soil, was accepted. To meet NDEP standards and to assure the impacted soil would not continually be a source for groundwater contamination the decision was made to adopt this level as the site clean-up goal for the impacted soil (Nevada Administrative Code, 1990).

A review of current NDEP and EPA policies and regulations indicates that the remedial objectives for petroleum hydrocarbon impacted groundwater are the following Maximum Contaminant Levels (MCL) for benzene, toluene, ethylbenzene, and total xylenes (BTEX):

NDEP Action Levels		
Contaminant	MCL	Unit
Benzene	5.0	µg/L
Toluene	1.0	mg/L
Ethylbenzene	700	µg/L
Total Xylenes	10	mg/L

The current NDEP policy for groundwater cleanup goals is to achieve the above mentioned MCLs. On a site-specific basis, higher BTEX concentrations may be acceptable pending NDEP approval. This allowance usually depends on site conditions, groundwater quality, receptors or public impact, and conditional cost of the remediation. A detailed risk assessment may be required by NDEP based on data collected during remedial actions (Nevada Administrative Code, 1990).

The remediation site displays several important features to consider when recommending remedial technologies and establishing the remedial action objectives:

1. There are numerous subsurface utilities located on-site and beneath the adjoining highway;
2. The site is an active convenience store, the operations of which cannot be substantially impacted;
3. A proposed Outlet Mall is planned for further construction at the site and adjacent properties;
4. Dissolved petroleum hydrocarbons are present in two on-site monitoring wells, monitoring wells 2 and 3, at concentrations of up to 56 mg/L TPH, 11,000 ug/L benzene, 23,000ug/L toluene, 1,200 ug/L ethylbenzene, and 13,000 ug/L total xylenes;
5. The Colorado River is located approximately 1,000 feet to the east of the site at an elevation similar to that of the on-site groundwater elevations.

Approximately 453 tons of readily accessible petroleum hydrocarbon impacted soil has been excavated and thermally treated off-site. The remaining hydrocarbon impacted soil is not readily accessible due to the presence of unstable sands and the proximity of South

Casino Drive, which happens to be a major highway in the city of Laughlin.

Additionally, removal of the remaining impacted soil would significantly disrupt the facility operations. This alternative is impractical due to the volume of soil and the economic burden placed on the retail operations (Stewart, 1997).

The impacted soil is located in the immediate vicinity of the former UST soil excavation between a depth of 10 and 25 feet bgs. Based on the headspace readings and analytical results of samples collected from the exploratory soil borings, the impacted soil is estimated to be present in a spherical zone approximately 12 feet thick, and extending over an apparent area of approximately 5,280 square feet centered on the former UST system.

The groundwater, both on-site and off-site, has been impacted by dissolved petroleum hydrocarbons. The groundwater remedial treatment system should be capable of remediating groundwater to the MCLs allowed for BTEX in the dissolved phase, or best achievable levels NDEP will allow.

5.2 POTENTIAL APPLICABLE RESPONSE ACTIONS

Generally applicable response actions that address the affected soil and groundwater at the former refueling station are identified and screened in this section. The remedial technologies surviving the screening process are developed into alternatives for more detailed assessment.

Typical technologies for soil remediation are excavation and on-site or off-site treatment, soil flushing, in-situ biodegradation, soil ventilation, or isolation.

Other remedial options include no action and monitoring of groundwater.

Typical technologies for groundwater remediation include groundwater extraction/treatment or reinjection, in-situ bioremediation, air sparging and vapor recovery, isolation, and containment.

SOIL REMEDIATION

Generally applicable remedial technologies commonly employed for TPH contaminated soil are as follows:

- **No Action/ Monitoring** - This is a baseline comparative option. When accompanied by fate and risk assessments, this option may provide sufficient data to evaluate the potential for groundwater impact and other exposure risks. It is not meet NDEP requirements for restoration of soil. Due to the presence of groundwater impact at the site and the distribution of soil impact, this option does not meet remedial goals. This option is therefore rejected (Code of Federal Regulations, 1991).

- **Containment/Horizontal Barriers** - Provides for the placement of a low permeability surface “cap” to control infiltration by surface water. In certain cases this option may modify fate and transport of contaminants to reduce the potential for groundwater impact. This technology will not remove the contaminant source area. Due to the presence of impacted groundwater, this option does not meet NDEP requirements. This option is therefore rejected (Code of Federal Regulations, 1991).

- **Excavation / Disposal** – Provides for excavation of contaminated soil and disposal to a permitted off-site facility or on-site treatment. The implementation of this general response action would create a major disruption to the facility activities, parking, and access the facility, and would involve excavating non-impacted overburden soil up to two to three times the volume of the contaminated soil. Additionally, shoring up or subsurface bracing would be required to prevent unstable sands from collapsing. This is not a practical alternative for the site. As stated in chapter one of this report 453 tons of contaminated soil was initially excavated. The cost of excavation, transportation, disposal, backfill and compact is approximately \$50 per ton. The initial excavation cost for the 453 tons was estimated to cost about \$23,000, if excavation is chosen another 1,500 tons will be excavated. The cost to excavate 1,500 tons would cost another \$75,000. Excavation would not treat contaminated groundwater, which would probably contaminate the soil once again. The main problem would not be excavation of the contaminated soil but would be trying to receive a permit to cut utilities near the main thoroughfare. Laughlin has implemented a strict not cut policy of utilities near or on the main thoroughfare.

Given all the above factors, an excavation and removal alternative would be risky and expensive. This option is therefore rejected.

- In-Situ Biological Treatment – Soil is maintained in a moist, oxygen-enriched state to promote aerobic bacterial degradation of the contaminants. The oxygen supply, the distribution of petroleum degrading bacteria, nutrients, and soil moisture conditions influence the success of in-situ biodegradation. The site conditions with regard to soil type, variability, particle size, and permeability appear to be conducive to this technology and does have a economic advantage (table1). However, the volatility of gasoline components and limited lateral migration of soil impact would favor other options (See Soil Ventilation). This option may be used, but put aside for the moment (U.S. Environmental Protection Agency, 1993).
- Soil Flushing – Contaminants trapped in the soil matrix above groundwater are flushed downward into the groundwater as means of remediation of the soil matrix. The contaminant removal from the environment occurs as part of the groundwater remediation. Flushing is accomplished by flooding water through the soil. The contaminant is transported downward both as a solute and in bulk due to hydraulic pressure. For remediation of soils containing hydrocarbons, surfactants have been used to increase hydrocarbon solubility and reduce surface tension. Soil flushing relies on highly permeable soil to allow sufficient water to be flushed through the soil mass. Hydrocarbons are generally not soluble in water, which hinders the flushing process. Regulatory agencies generally do not permit the addition of agents such as surfactants to the water, which may be used for beneficial purposes. Soil flushing actually increases groundwater contamination and good control of groundwater flow is essential. The flux in groundwater can aggravate control problems. Due to the presence of a low permeability clay horizon, the control of the soil flushing would be difficult. This option is therefore rejected (U.S. Environmental Protection Agency, 1993).
- Soil Ventilation – Soil ventilation is a well-proven alternative for remediation of the unsaturated zone and capillary fringe soils for gasoline and occasionally diesel when properly implemented. The method is applicable to volatile constituents in high to moderately permeable soil and can be designed to work in low permeability soil. Volatile compounds, trapped between soil particles as small liquid drops and adhering to the soil particles in thin liquid layers, exist in equilibrium with the soil vapor (air). When the contaminated vapor is withdrawn from the soil mass, it is replenished from the perimeter or the surface with vapor deficient “clean” air. The equilibrium is quickly reestablished by vaporization of the volatile liquid into the clean air. Repeated flushing of the soil mass with the clean air results in remediation of the volatile constituents in the soil (U. S. Environmental Protection Agency, 1991).

At the surface, the contaminant-laden air must generally be treated prior to discharge to the atmosphere. Treatment methods most commonly employed are thermal oxidation with or without catalyst and carbon adsorption.

The movement of air through the soil immediately above the groundwater will assist in remediation of the groundwater. Removing the contaminant source prevents further contamination and need to treat water. Salvage value on equipment is estimated to be about 40 to 50% and can be sold to be used at other sites (refer to table 2). Therefore this option is accepted (U. S. Environmental Protection Agency, 1991).

GROUNDWATER REMEDIATION

- **No Action / Monitoring** – This is a baseline comparative option. In situations where groundwater impact is minimal or only soil contamination is present, this option may be accepted. However, due to the presence of dissolved phase hydrocarbons well above NDEP action levels, an active remedial alternative is required. This option is rejected.
- **Groundwater Extraction / Treatment / Discharge** – In this option groundwater is extracted using recovery wells. The extracted groundwater is treated by the extraction of hydrocarbons from the water or destruction of the hydrocarbons in the water, then with permission and a permit from the Sanitation District, the treated water is released into the sewer system.

TREATMENT OPTIONS

- **Air Stripping** – This method removes the dissolved petroleum hydrocarbons through volatilizing these compounds into an air stream. Air emissions controls may be required for the VOCs in the air stream. This treatment is an option.
- **Carbon Adsorption** – The groundwater is passed through a bed of granular activated carbon in which the organic compounds adhere to the carbon. The loaded carbon is disposed of at an off-site treatment facility. Use of carbon adsorption liquid units alleviates the need for air emission control in groundwater treatment. However, carbon usage rates and disposal costs could be high. This option is retained for further evaluation.
- **UV Oxidation** – Ultraviolet light is used in combination with an oxidizing agent (hydrogen peroxide) to oxidize the organic compounds in the water into inorganic compounds and water. This option does not provide a technical or economic advantage at this site (refer to table 3). This option is therefore rejected.

Note:

The above options pump contaminated groundwater out to be treated, but does not treat the source of the problem. The dense soil works much like a sponge, when the soil becomes saturated the soil will release the hydrocarbons and will take approximately 2 to 5 years to fully eradicate using a pump and treat method.

- **Groundwater In-Situ Treatment** - The following options treat the groundwater in the surface, preventing the need to extract, treat, and discharge groundwater.
 - **In-Situ Bioremediation** – Groundwater is physically or chemically oxygenated and nutrients are added to facilitate biodegradation. The site conditions with regard to soil type, variability, particle size, and permeability are conducive to this technology. Hydrogeologic modeling and feasibility testing indicated this option would be technically feasible. Sufficient nutrients (nitrates and phosphates) appear to be present in the groundwater. Hydrogeologic control of the operation can be demonstrated and maintained at this site. This option is therefore accepted.
 - **Air Sparging** – Air is introduced into the aquifer through air sparging wells screened at or near the bottom of the impacted groundwater. The air bubbles up through the groundwater entraining volatile organic compounds (VOCs) and physically oxygenating the groundwater. The VOC-laden air enters the unsaturated zone where it is recovered by soil ventilation. The introduction of oxygenated air also encourages biological activity in the groundwater and soil.

This method in combination with a soil ventilation recovery system appears feasible. This option would be technically feasible for gasoline impacted groundwater at the site. This option is therefore accepted (Stewart 1997).

5.3 **SOIL REMEDIATION ALTERNATIVES**

The following section presents a discussion of the surviving soil remediation alternatives as they relate to soil remediation objectives, as set by NDEP. The Containment/ Horizontal Barriers, Excavation/Disposal, and Soil Flushing alternatives have been eliminated, as they are clearly not feasible nor cost effective at the former refueling station. The In-Situ Biological Treatment option has been tentatively accepted in combination with Soil Ventilation based on the economic advantages (refer to table 1).

5.3.1 **No Action/Monitoring**

The no action alternative serves as baseline against which the feasibility of the remedial alternatives is judged in the comparative analyses. No actions would be taken for soil restoration and source removal. Monitoring of groundwater would

be conducted to evaluate impact of residual soil contamination on groundwater clean-up activities.

5.3.2 Soil Ventilation and Biodegradation

Description-The use of soil ventilation to remove volatile compounds from the soil and enhance biodegradation is an efficient and cost effective method of remediation. A soil ventilation biodegradation system would be installed to reduce the amount of TPH concentrations in the unsaturated zone to below current regulatory action levels. This would be accomplished by placing the soils under a vacuum, thereby removing the volatile organics from the soil pore spaces and providing oxygen for aerobic biodegradation. The soil ventilation could also assist the groundwater remediation by volatilizing compounds from the dissolved phase petroleum hydrocarbons in the aquifer (Stewart,1997).

The system would not be able to extract the heavier molecular weight semi-volatile chemicals due to their physical characteristics. These constituents, which are generally considered immobile, would remain in the soil to be degraded by bacterial activity and would represent a minor component of gasoline constituents.

The system would consist of vertical soil ventilation wells installed in areas where the soil has been impacted by petroleum hydrocarbons. Vapors would be drawn to the surface using high volume, negative pressure blower. Gasoline laden vapors would be treated for air emission control using the Best Available Control Technology (BACT), which is thermal/catalytic oxidizer or carbon absorption.

Effectiveness - This alternative has proven both cost effective and efficient for similar UST remediation projects in reducing TPH concentrations below the current NDEP remedial objectives for soil impacted by gasoline.

Most successful soil ventilation projects have been taken place in sandy soils with less success in silts, clay soils, or cliche. Standard soil ventilation requires closer well spacing and higher volumes in low permeability soils because the rate of contaminant removal is directly related to the soil gas ventilated. The rate of soil gas ventilation is less a factor in soils which are limited by desorption of contaminants and their diffusion through soil micropores. By selecting proper screen intervals in the soil ventilation wells, problems related to low permeability clay horizons could be avoided (Stewart, 1997).

Implementation - This remedial alternative would be implemented by designing, installing, and operating a system that consists of vertical soil ventilation wells, a vacuum blower, a moisture knock-out pot, and air emission control by thermal/catalytic oxidizer or carbon adsorption treatment units. Electrical power for the system blower would be obtained from existing power at the site. The time required to reduce the constituent concentrations below the treatment objectives is expected to be approximately one to three years. This is a preliminary evaluation subject to refinement during the detailed design phase. Confirmatory soil sampling would be conducted to assess if the treatment objectives have been met. Confirmatory soil samples would be collected after treatment using two to three exploratory soil borings and collecting samples from the zone of hydrocarbon impacted soil. The samples shall be laboratory analyzed

for TPH concentrations and would have to meet or exceed the NDEP remediation goal of 100 mg/kg (Nevada Administration Code, 1990). Areas not achieving the remediation goals would be resampled following further treatment.

Cost - Cost for implementation of this alternative is estimated at up to \$178,500 to \$193,500, as shown in Table 1. This cost includes capital and engineering costs for construction of the system, permitting, power operating costs for one year, system maintenance, confirmatory sampling and analysis, and a site closure report (Dataquest, Inc.1994).

5.4 GROUNDWATER REMEDIATION ALTERNATIVES

The following section presents a discussion of surviving groundwater remediation alternatives as they relate to groundwater clean-up goals and objectives. Factors addressing the selection of Extraction/Treatment/Discharge options versus In-Situ treatment options are discussed below.

5.4.1 No Action / Monitoring

The no action alternative serves as a baseline against which the feasibility of the remedial alternatives are judged in the comparative analyses. The site would be left in its current condition with no action taken for groundwater remediation, but long-term groundwater monitoring would be implemented. This alternative would provide baseline data from which to assess (through future sampling of groundwater) contaminant migration and effectiveness of remedial actions. Note that this option alone does not meet current NDEP requirements. However, monitoring would supplement aggressive remedial actions.

5.4.2 Groundwater Extraction by Pumping

Description - Affected groundwater would be extracted using groundwater recovery wells and treated in an air stripper or carbon adsorption units. Treated water would be discharged to the sanitary sewer by permit from the Sanitation District. Air emissions controls of the air stripper air stream would consist of a thermal/catalytic oxidizer or carbon adsorption units.

5.4.2.1 Treatment by Air Stripping

Description - Air stripping is a widely used treatment method for removing volatile organic compounds from groundwater. Air stripping involves providing intimate contact between air and water to promote mass transfer of volatile organics at the air/water interface. This treatment system provides high liquid interfacial area for efficient mass transfer and operation of high air-to-water volume ratios is possible because of the low-pressure drops associated with most systems. High volatile constituent removal efficiency generally results. Treated water would be discharged to the sanitary sewer.

Effectiveness

Air stripping has proven to be effective for remediation of groundwater contaminated with volatile organic compounds. The process is effective for the organic compounds in gasoline. This method is most effective in separating volatile dissolved phase hydrocarbons from water.

Implementation - This remedial alternative would be implemented by designing, installing, and operating a system consisting of: existing and newly installed groundwater recovery wells, pneumatic groundwater recovery pumps, an air

compressor, an equalization tank, a low-profile tray air stripper with blower, and an air emissions control by either thermal/catalytic oxidation or carbon adsorption treatment units. Electrical power for the air compressor and air stripper blower would be obtained from existing power at the site. Treated water discharge would be piped to the sanitary sewer. The time frame for groundwater remediation is expected to be approximately three to five years. Monitoring of system influent concentrations and groundwater monitoring wells would be performed to assess if remediation objectives have been met. Groundwater monitoring would continue for one-year after the clean-up goal has been achieved.

Cost - Cost for implementation of this alternative is estimated at up to \$99,000 as shown in Table 4. This cost includes capital and engineering costs for construction of the system, permitting, and power operating costs for one year, system maintenance, monitoring, sampling and analysis (Dataquest, Inc 1994).

5.4.2.2 Treatment by Carbon Adsorption

Description - Carbon adsorption is a commonly used treatment method for removing organic compounds from groundwater. Carbon adsorption involves passing the contaminated groundwater through a bed of activated carbon in which organic compounds adhere to the carbon particles. This treatment system provides for efficient removal of organic compounds from water without the need for air emissions controls. The system effluent is monitored periodically for breakthrough of organic compounds at which time the loaded carbon is removed and disposed of at an off-site treatment facility.

Effectiveness - Carbon adsorption has proven to be effective for remediation of groundwater contaminated with organic compounds. The process is effective for the organic compounds in gasoline. This method is most effective in separating dissolved phase hydrocarbons from the water.

Implementation - This remedial alternative would be implemented by designing, installing, and operating a system consisting of: existing and newly installed groundwater recovery wells, pneumatic groundwater recovery pumps, an air compressor, an equalization tank, two carbon adsorption units arranged in series, and a discharge pipeline. Electrical power for the air compressor would be obtained from existing power at the site. Treated water discharge would be piped to sanitary sewer. The time frame for groundwater remediation is expected to be approximately three to five years. Monitoring of system influent concentrations and groundwater monitoring wells would be performed to assess if remediation objectives have been met. Groundwater monitoring would continue for one-year after the clean-up goal has been achieved.

Cost - Cost for implementation of this alternative is estimated at up to \$ 122,000 as shown in Table 3. This cost includes capital and engineering costs for construction of the system, permitting, power operating costs for one year, loaded carbon disposal and replacement, and system maintenance, monitoring, sampling, and analysis (Dataquest, 1997).

5.4.3 In-Situ Groundwater Remediation

Description - The affected groundwater would be remediated in place using air-sparging wells screened below the contaminated aquifer. Volatile compounds would be stripped from the groundwater and recovered through soil ventilation. Groundwater would be physically oxygenated through contrast with the sparge air stream enhancing biodegradation of petroleum compounds within the aquifer.

Effectiveness - Air sparging is becoming a more favored means of groundwater remediation. This method is effective at removing dissolved volatile compounds from the groundwater and making them available for recovery through negative pressure soil ventilation wells. Oxygen introduced into the groundwater through the air sparging wells increasing the dissolved oxygen (DO) content of the groundwater promoting aerobic biodegradation of the dissolved petroleum hydrocarbons. Remediation of the groundwater takes place in-situ removing the need for surface treatment and water discharge.

Implementation - This remedial alternative would be implemented by designing, installing, and operating a system consisting of: groundwater air sparging wells and an air compressor. Electrical power for the air compressor would be obtained from existing power at the site. The time frame for groundwater remediation is expected to be approximately one to three years. Groundwater TPH and BTEX concentrations and DO contents would be monitored periodically. Groundwater elevation measurements would be monitored to evaluate the influence of air sparging and soil ventilation on groundwater flow patterns. Groundwater monitoring would continue for one year after the clean-up goal has been achieved.

Cost - Costs for implementation of this remedial alternative is estimated at up to \$78,000 as shown in Table 1. This cost includes capital and engineering costs for construction of the system, installation of air sparge wells, power operating costs for one year, system maintenance, monitoring, sampling and analysis. Air emission controls and air permitting are included with the soil ventilation cost estimates. No water discharge permits would be required (Dataquest, Inc, 1994).

5.5 **SUMMARY**

The previous sections present a discussion and screening of applicable remedial alternatives as they relate to the former refueling station site specific objectives and current remediation practices in the State of Nevada. These technologies were screened for their application at the site.

Site condition and constraints have eliminated many of the options employed for remediation due to technical feasibility or cost effectiveness at this site. However, our assessment finds that soil ventilation in combination with groundwater air sparging and enhanced biodegradation will be technically feasible, applicable, and cost effective at the site.

6.0 SELECTED REMEDIAL ALTERNATIVE – CONCEPTUAL DESIGN

The previous section presented a discussion of applicable technologies as they relate to the former refueling station, site-specific objectives. The remedial alternatives were screened for their application at the site. This screening process ruled out several remedial technologies that are clearly inappropriate for this site. This allowed the focus to be on appropriate surviving remedial alternatives which included a description of the effectiveness, implementation, and estimated costs.

Therefore, considering the site specific remediation objective and the critical selection criteria outlined in Section 5.0, soil ventilation and groundwater air sparging with enhanced biodegradation will be used for this site. This soil contamination is apparently confined to a roughly elliptical area of unsaturated soil between 10 to 25 feet bgs. Groundwater is impacted by dissolved phase petroleum hydrocarbons trending to the southeast of the release point.

6.1 SOIL VENTILATION AND ENHANCED BIODEGRADATION

The overall site layout and remedial system components including the soil remediation design. The soil ventilation system employs five proposed vertical soil ventilation wells. A moisture knock-out, an explosion proof high volume vacuum blower, and a thermal/catalytic oxidizer or carbon adsorption units, arranged in series, will be required to perform the soil ventilation and air emission controls of exhaust vapors. The location of the treatment system is initially flexible; however, it should be installed as near as possible to the vertical soil ventilation wells to reduce the vacuum

requirements and friction loss. After the soil ventilation lines are installed, plans should be made to leave the above ground system at its location for up to one to three years. This remedial alternative is recommended based on subsurface soil conditions, on-site utilities and structures, facility impact, effectiveness, and economic considerations.

Vertical soil ventilation wells will be drilled and installed with slotted sections in the petroleum hydrocarbon impacted soil zones. The wells will be connected to a vacuum blower to volatilize and recover petroleum hydrocarbon vapors and draw oxygen-enriched air into the impacted soil zone to stimulate aerobic biodegradation.

The heart of the system is a vacuum blower that extracts the volatile organic compounds from the soil pore space. The contaminated air is then diverted to a moisture knockout pot for condensate removal. The air stream from the knockout pot is then directed to a thermal/catalytic oxidizer or carbon adsorption units for hydrocarbon removal (Stewart, 1997).

6.2 GROUNDWATER AIR SPARGING – CONCEPTUAL DESIGN

It is anticipated that the system will be composed of six to seven groundwater air sparging wells. System modifications will be made following start-up of the remedial system to accommodate site-specific conditions.

The air injection system will be directed through subsurface piping manifold from an air compressor to the air sparging wells. Air is introduced into the aquifer through air sparging wells screened at or near the bottom of the impacted groundwater. The air

bubbles up through the groundwater entraining volatile organic compounds (VOCs) and physically oxygenating the groundwater. The VOC-laden air enters the unsaturated zone where it is recovered by soil ventilation. The introduction of oxygenated air also encourages biological activity in the groundwater and soil.

Additional detail such as the remedial system details, valves, flow metering, control panels, alarms, procedures, start-up and shut-down, etc., will be handled in the detailed design phase of the project. The air sparging wells will be installed prior to construction of the remedial system. The pressurized air lines and soil ventilation lines will be installed in subsurface trenches of sufficient depth (three to four feet bgs) to avoid interfering with future construction activities (Stewart, 1997).

6.3 PERMITTING

Regulatory compliance permits for soil and groundwater remediation are required prior to installation and operation of the remedial system. The Clark County Health District Air Pollution Control District (CCHD-APCD) will be contacted regarding the details for air emissions controls based on expected air emission rates. Low emissions are expected to the atmosphere with the selected air emission controls. The permit requirements are as follows:

6.3.1 Air

Based on the laboratory sample results for soil and groundwater from the site, the estimated initial VOC emissions will be calculated. If emission rates exceed the

current APCD emission limit, BACT air pollution control abatement equipment will be required.

The APCD requires an Authority to Construct (ATC) permit to installation and operation of the soil and groundwater remediation system. Once the ATC permit has been granted, an operating permit must be obtained and a system inspection performed by the APCD prior to operation of the system.

6.3.2 Water

Permits will be required from the Division of Water Resources (DWR) for the installation of the air sparge wells and the appropriate waivers related to these installations.

No water discharge permits or groundwater appropriation permits will be required because of the selected in-situ remedial option, no water will be discharged. All groundwater is treated in place.

6.4 COST ESTIMATES

As presented in Section 5.0 total costs for site remediation are estimated at up \$257,000 to \$272,000. Capital cost range from \$86,000 to \$101,000 and includes additional well installation, and remedial equipment. Installation costs are expected to be up to \$70,500. Costs for operation, maintenance, monitoring, sampling, laboratory analyses, progress reports, confirmatory sampling, engineering services, and closure reports are estimated to be up to \$100,500 (Dataquest, Inc, 1994).

7.0 RECOMMENDATIONS

When making decisions among various alternatives it is common practice in the business world to use a cost benefit analysis to evaluate the alternatives before making a decision. Using a cost benefit analysis allows one to evaluate the cost of making a decision against the benefits of that decision. After evaluating each alternative one would choose the alternative with the best balance of both cost and benefit.

7.1 Preferred Remedial Action-Soil Ventilation & Biodegradation

Cost- As stated in section 5.0 total cost for site remediation are estimated to be between \$257,000 to \$272,000 annually. With the length of remediation time estimated to be between 18 to 24 months, this calculation was derived from similar sites using the same technologies.

Benefits- The benefits derived by using bioremediation in conjunction with soil ventilation addresses the concern of the public, which is the removal of the petroleum hydrocarbons. The installation of the wells for soil ventilation makes the alternative of bioremediation practical to use and cost effective (refer to Table 1 & 2). This type of remediation not only addresses both the soil and groundwater contaminant, but is one of the faster clean-up methods. Soil ventilation and biodegradation allows construction of an factory outlet mall to continue without any interference.

7.2 No Action Alternative

Cost- The no action alternative has no such financial cost, but is not an acceptable alternative method by NDEP standards.

Benefits- There are no benefits if no action is taken except for the owner of the refueling station, in which he or she may not bear the financial burden.

7.3 Containment/Horizontal Barriers

Cost- Capital cost for containment/barriers will be, at most, a few thousand dollars for capping the surface with a pavement cap to eliminate infiltration by surface water. This action does not meet NDEP requirements.

Benefit- Capping the contaminated soil and groundwater only benefits the responsible party by not having to pay the clean-up cost.

7.4 Excavation /Disposal

Cost- The financial cost to excavate the contaminated site would cost approximately \$92,000. The surrounding business would also be disrupted during excavation and would have a financial burden put on them. Groundwater is not treated by this method, only the impacted soil. Contaminated groundwater is likely to saturate the soil with hydrocarbons again.

Benefit- The benefits to this method is that soil is almost immediately treated.

7.5 Soil Flushing

Cost- Soil flushing would increase groundwater contamination and control of the water would be too difficult due to the density of the soil content. Sufactants which are used to increase hydrocarbon solubility are not usually permitted by regulatory agencies.

Benefits- Benefits would only be to the soil and not to the contaminated groundwater.

7.6 Summary

Due to NDEP requirements, the no action alternatives and contaminant alternative can not be utilized because they do not meet regulatory standards. Excavation/ Disposal does not treat nor clear-up the contaminated groundwater, this type of remediation only addresses the contaminated soil. Excavation would also disrupt businesses, which would place an unwanted financial burden on them. Soil flushing addresses the soil contaminate, but has a potential to spread the groundwater contaminate into water sources, such as the Colorado River.

Soil Ventilation and bio-remediation alternatives clean both soil and groundwater contamination at a comparatively low cost, without affecting the surrounding businesses. This type of action meets NDEP standards and regulations. Taking into account the low cost and thorough clean-up, by using both soil ventilation and bio-remediation, this method should be utilized at this particular site.

8.0 CONCLUSION

In conclusion, while evaluating this contaminated site I found that there is no clear blueprint that can be followed. With a variety of environmental conditions possible and different resources available to each site, it is impossible to name one method of abatement universally applicable to all case scenarios. Each site must be analyzed from top to bottom comparing a variety of different alternatives. A variety of different factors must be taken into consideration when making these comparisons, such as: cost, level of clean-up, regulations, training of staff, site specific parameters, and possible disruption of the community. A methodical analysis of the alternatives is the only way to find a satisfactory solution for all parties involved.

9.0 TABLES

10.0 REFERENCE

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