Green Zia Analysis of
Johnson Controls Northern New Mexico
Petroleum Spill Wastes

Background

Johnson Controls Northern New Mexico (JCNNM) is the facility support subcontractor to the Los Alamos National Laboratory (the Laboratory), in Los Alamos, New Mexico. JCNNM operates and maintains the Laboratory facilities, equipment, property, grounds, infrastructure, and public and private roadways covering over 27,800 acres. All JCNNM work is conducted on behalf of the Laboratory and the Department of Energy (DOE).

JCNNM services include heavy equipment operation in support of roadway maintenance, sanitary waste collection, recycling operations, construction activities, utilities work, grounds maintenance, and transportation, among others. During DOE Fiscal Years (FY) 1998, 1999 and 2000, approximately 58 percent of the regulated wastes generated, managed and disposed of by JCNNM were directly attributable to spills of petroleum products from heavy equipment.

As part of their commitment to pollution prevention (P2), the JCNNM Environmental (HENV), Grounds (MDSG) and Heavy Equipment (MDHE) Branches initiated an effort to identify alternatives that would prevent spills from heavy equipment. Working with the Laboratory's Environmental Stewardship Office (ESO), Water Quality and Hydrology Group (ESH-18), and Hazardous and Solid Waste Group (ESH-19), JCNNM personnel began a systematic process to evaluate and implement P2 opportunities for heavy equipment operations.

This paper presents the approach used by JCNNM and the Laboratory to reduce pollution caused by petroleum leaks from heavy equipment. This approach utilizes the *New Mexico Green Zia Systems Analysis Tools* (Green Zia tools), as specified in Function Area 3 (Managerial Accomplishments) of Section B, Part II-1, Appendix F of the DOE/University of California contract (2000). The Green Zia analyses employed in this project were generally accomplished according to the New Mexico Green Zia Environmental Excellence Award Program guidance at *http://www.nmenv.state.nm.us*. In some cases, the specific challenges presented by the wide variety of heavy equipment use necessitated the customization of the Green Zia tools. This is one of three Green Zia analyses that JCNNM has completed to satisfy Goal 3 of Performance Measure 29, "Hazardous Waste Generation," in JCNNM's contract with the Laboratory.

JCNNM applied the following Green Zia tools:

- Process mapping of spill responses associated with heavy equipment operations
- Identification and rank ordering of P2 opportunities
- Activity-based costing analysis
- Root cause analysis
- Consensus problem statement
- Generating P2 alternatives
- Selecting appropriate P2 alternatives
- Implementing the selected alternatives with a formal action plan

JCNNM has an ongoing and formal P2 program committed to reducing waste and environmental releases. The P2 program is documented in a written plan (*The Waste Minimization/Pollution*

Prevention Program Plan for Calendar Years 1997 through 1999, SPI 12-31-012) and P2 practices are incorporated into operating procedures, where appropriate. In addition, Performance Measure 29 of JCNNM's contract with the Laboratory requires P2 activities, which are tied to the subcontract award fee. These documents specify JCNNM commitment to preventing waste at the source, while also recycling and minimizing waste that has not been prevented. In addition, Performance Measure 29 establishes numeric goals for reduction of wastes, requires tracking and reporting of progress toward meeting the goals, and provides incentives or rewards for waste reduction. Under JCNNM's P2 program, Department and line managers are challenged and required to incorporate P2 practices to the extent technically and economically feasible.

The Challenge

From October 1997 to March 2000, JCNNM has generated approximately 41 metric tons of regulated wastes (RCRA hazardous wastes and NM Special wastes). Of that total, petroleum spill waste accounted for approximately 58 percent. Because this is JCNNM's largest regulated waste stream, it represents a significant regulatory liability.

In addition, in October 1999, the Laboratory instituted a recharge fee for waste disposal of $11.75 per kilogram. DOE Defense Programs (DOE-DP) subsidized $11.00 of this for JCNNM operations. JCNNM was responsible for the remaining $1.75 per kilogram.

The challenge for JCNNM and the Laboratory was as follows:

- Determine the costs associated with the petroleum spill problem, including labor, waste management and material costs.
- Identify characteristics common to most petroleum spills and evaluate these characteristics to determine their impact on the total waste stream.
- Identify, rank and implement P2 alternatives for the common causes of petroleum spills, with the specific intent of reducing waste management costs and regulatory liability.

Green Zia Petroleum Spill Waste Team

A multi-disciplinary team was formed to address prevention of petroleum spills and their associated wastes. The team included personnel familiar with heavy equipment use and maintenance, as well as those knowledgeable about the root causes of JCNNM's spills. The following individuals were members of this team:

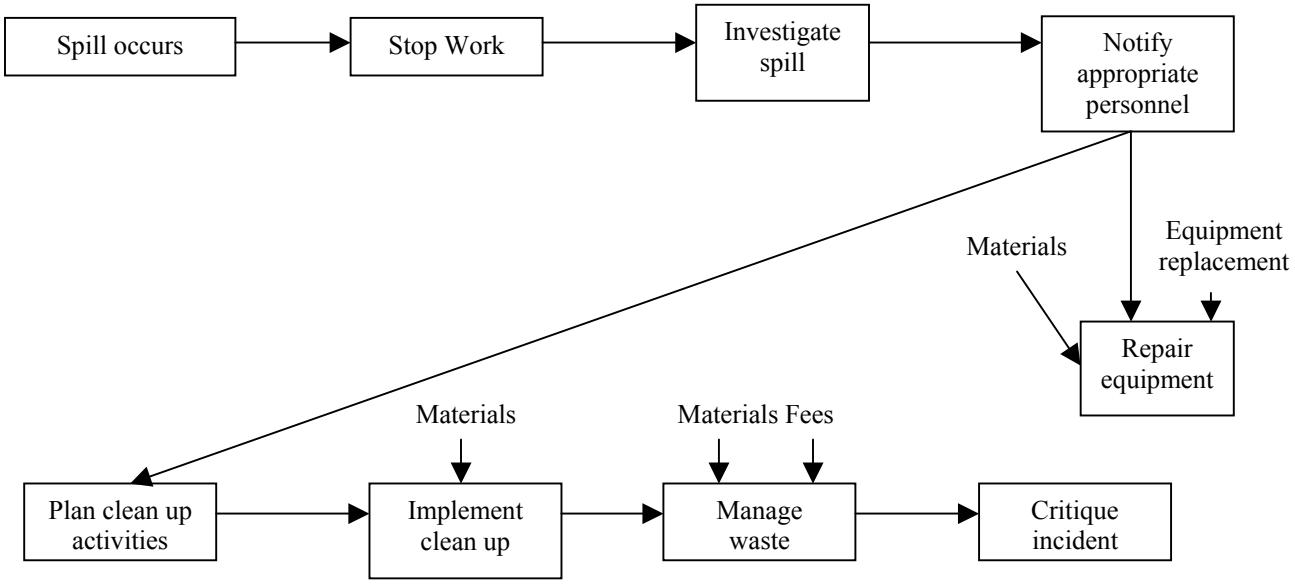
- Dianne Wilburn, Technical Communications Manager, EDO, LANL
- L. Vince Rodriguez, RCRA Program Coordinator, JCNNM-HENV/BEC
- Richard Perkins, Solid and Liquid Waste Program Coordinator, JCNNM-HENV/BEC
- John Keene, Heavy Equipment Branch Supervisor, JCNNM-MDHE
- Manny L'Esperance, Grounds Branch Supervisor, JCNNM-MDSG
- Harvey Decker, NPDES Outfall Team Member, ESH-18, LANL
- Debbie Finfrock, Solid Waste Program Manager, ESH-19, LANL
- Jim Stanton, P2 Program Coordinator, JCNNM-HENV/BEC
- David Hill, Safety Engineer, JCNNM-HSFT

This team met on several occasions to complete the work on this project.

Process Characterization

The team prepared a process map for typical spill responses (see Figure 1). Each step includes labor costs, which are not shown in Figure 1 but are addressed under Activity Based Costing, below.

Figure 1. Detailed Process Map Illustrating Typical Spill Response



Activity-Based Costing

There are a variety of costs associated with each step in the spill response process. Tables 1 and 2 describe these costs in detail.

Table 1: Summary of Spill Response Costs

		Current Costs			Estimated Savings		
Item No.	Description	Estimated Cost/spill	Spills per Year	Estimated Annual Cost	Cost Savings per Spill	Annual Cost Savings	% ROI
1	Stop Work	$436.45	12	$5,237.38	$305.51	$3,666.16	
2	Notify Appropriate Personnel	$77.56	12	$930.76	$54.29	$651.53	
3	Investigate Spill	$913.45	12	$10,961.38	$639.41	$7,672.96	
4	Plan Cleanup Operation	$237.88	12	$2,854.52	$166.51	$1,998.17	
5	Implement Cleanup	$1,194.81	12	$14,337.74	$836.37	$10,036.42	
6	Manage Wastes	$26,613.00	12	$319,356.00	$18,629.10	$223,549.20	
7	Critique Work	$1,111.76	12	$13,341.14	$778.23	$9,338.80	
8	Fix Equipment	$358.00	12	$4,296.00	$250.60	$3,007.20	
	TOTALS	**$30,942.91**		**$371,314.92**	**$21,660.04**	**$259,920.44**	
	Implement Action Plan 1st Year			**$81,665.31**			
	Implement Action Plan Out Years			**$27,843.46**			**264.2**

Table 2: Item Category Summary Table

		Current Costs			Estimated Savings		
Item No.	Description	Estimated Cost/spill	Spills per Year	Estimated Annual Cost	Cost Savings per Spill	Annual Cost Savings	%ROI
1	Labor	$4,202.36	12	$50,428.32	$2,941.65	$35,299.82	
2	Materials	$590.55	12	$7,086.60	$413.39	$4,960.62	
3	Fees	$26,150.00	12	$313,800.00	$18,305.00	$219,660.00	
	TOTALS	**$30,942.91**		**$371,314.92**	**$21,660.04**	**$259,920.44**	
	Implement Action Plan 1st Year			**$81,665.31**			
	Implement Action Plan Out Years			**$27,843.46**			**264.2**

Root Cause Analysis

Determining the root cause of spills from heavy equipment was difficult due to a lack of previously collected data; a large, diverse fleet; and the numerous potential factors involved in any given spill. Spill reports over the past three years indicated general causes (Table 3), but not specific causes (i.e., line burst due to over pressurization or hose connection failed due to ferrule damage). Further, JCNNM maintains a heavy equipment fleet of approximately 150 vehicles of about 15 different types (cranes, backhoes, etc.). Each piece of equipment has different

vulnerabilities and use patterns that influence how a spill may occur. However, even with the diversity of equipment and multiple possibilities for spills, the team was confident that it could identify the key causes of spills.

The team determined that two equipment types (backhoes and packmasters) were responsible for the majority of heavy equipment spills. In most cases, backhoes and packmasters had hydraulic oil spills caused by failed, abraded or torn hydraulic lines. Based on personal observations, MDHE personnel believed that most line failures were caused by damaged end fittings (ferrules), rather than hose ruptures. Spills from the packmaster were almost always due to abrasion of one or two specific hydraulic hoses. Finally, operator errors (such as catching a hose on a tree limb) were responsible for many torn hoses on backhoes.

Table 3: General Causes of Petroleum Spills Since 1996

Cause of Spill	Percentage of Total
Equipment line failure (e.g., hydraulic line)	42%
Improper procedure	21%
Crashes	5%
Overheating	10%
Unknown	21%

Statement of Problem

Petroleum contaminated spill wastes from heavy equipment operations constitute a significant concern because of their large volumes and associated liabilities and waste disposal costs. Although spills are nonroutine and unpredictable, the team examined the spill response process and available root cause data in an effort to identify potential prevention strategies. The team identified several items that contribute to spills, increase their environmental impacts, and/or hinder efforts to eliminate them:

- Lack of employee awareness of the impacts of spill wastes and of the means to prevent, mitigate, and respond to spills;
- Investigation practices that were insufficient to determine root causes of spills;
- Hydraulic oil lines on specific pieces of equipment that burst at their end fittings or fail as a result of abrasion; and
- Use of petroleum-based oils when non-toxic bio-based oils are available.

Generating Process Alternatives

The team used a brainwriting tool to develop 30 potential alternatives for addressing petroleum contaminated spill wastes. They are as follows:

1) Improve education on the environmental and financial impacts of spills.
2) Modify work practices such that less heavy equipment was used at the Laboratory.
3) Improve project planning to include a focus on spill prevention and reporting.
4) Use pneumatic instead of hydraulic equipment.
5) Replace petroleum-based oils with nontoxic bio-based oils.

6) Manage any nontoxic oil spill waste as municipal solid waste rather than as NM Special waste when possible.
7) Use secondary seals on primary leak spots.
8) Investigate and improve hose quality.
9) Sheath the hoses with exterior protective hoses designed to contain oil when inner hoses fail.
10) Implement a hose replacement schedule.
11) Install low-pressure alarms on all hydraulic lines.
12) Reroute any vulnerable hoses.
13) Place steel mesh around vulnerable hoses.
14) Place soft, absorbent hose diapers around vulnerable hoses.
15) Use longer hoses to reduce sharp bends.
16) Place hose cages around vulnerable hoses to protect them from branches, etc.
17) Have every unit equipped with spill kits and absorbent pads.
18) Have sub-contractors, who are contractually required to cleanup and manage their own spill wastes, perform all heavy equipment work.
19) Never do work that requires heavy equipment.
20) Establish procedures for high-quality, pre-job operator inspections of hydraulic line integrity.
21) Change the aluminum ferrules to steel ones to keep hoses from blowing off their ends.
22) Provide financial incentives to operators who prevent spills (similar to safety incentives).
23) Improve MDHE mechanics' responses to leak reports and prevent small leaks from becoming large spills.
24) Institute a contractual preference for sub-contractors that use non-toxic, non-petroleum industrial oils.
25) Convince EPA to regulate non-toxic, vegetable-based industrial oils under 40 CFR 279.
26) Train all operators on spill prevention and response.
27) Regularly inspect parked heavy equipment for leaks and spills.
28) Move all heavy equipment parking areas away from storm water run-off.
29) Perform post-work vehicle and environment inspections to identify new leaks.
30) Integrate environmental concerns into the 5-step ISM process.

Selecting an Alternative

Members of the Green Zia Spills team felt that the best way to reduce the liabilities and costs associated with petroleum spill wastes was to prevent most spills and mitigate those that did occur. The team used a bubble-up/bubble-down tool to combine and categorize alternatives, while also eliminating some alternatives based on feasibility, cost, and safety concerns. Ultimately, the team developed a multifaceted implementation plan, with many alternatives that have equal priority for implementation.

The alternatives that the team selected for implementation are shown below.

Educational Activities: The following activities are expected to increase employee and management awareness of the environmental and financial impacts of spills from heavy equipment, train operators to mitigate small spills, integrate environmental issues into day-to-day operations, and improve data collection for better root cause analysis.

1. Educate heavy equipment operators and supervisors on the financial impacts of spills.
2. Train all operators on initial spill prevention, reporting and response (including spill kit use), and provide regular refresher training.
3. Include environmental concerns in pre-job briefings and tailgate meetings, along with the 5-step ISM process.
4. Train operators to do high-quality, pre-job inspections of the equipment, focusing on leaks.

5. Educate project planners on the financial and environmental impacts of spills, with the goal of improving project planning.
6. Educate MDHE mechanics on the importance of asking for spill reports or reporting spills associated with maintenance calls (i.e., if they are repairing a blown hydraulic line, a spill probably occurred and HENV and MDSG should be involved).

Maintenance Activities: The following activities are expected to decrease equipment failure rates, provide the means to mitigate spills, and replace regulated oils with non-regulated oils.

1. Investigate the feasibility of replacing petroleum-based oils with non-toxic oils.
2. Improve MDHE response to leak reports.
3. Change aluminum ferrules to steel ferrules.
4. Investigate vulnerable hoses and re-route if necessary and practical.
5. Put spill kits and recyclable absorbents in every piece of heavy equipment.
6. Continue replacing old equipment as funding becomes available.

Administrative Activities: The following activities are expected to streamline the use of bio-based oils, improve data collection, and integrate environmental issues into day-to-day operations.

1. Deregulate non-toxic oils.
2. Petition EPA to include bio-based (i.e., vegetable) oils under 40 CFR Part 279.
3. Improve communication between HENV, MDSG and MDHE personnel.
4. Institute a policy of contractual preference to contractors who use non-toxic oils and who are responsible for their own spill waste management.
5. Regularly inspect parked heavy equipment for leaks.
6. Integrate environmental concerns into the 5-step ISM process, from upper management to the workers.
7. Dedicate an operator for each vehicle to perform daily inspections.
8. Return heavy equipment to MDSG or MDHE custody as soon as possible.
9. Move all heavy equipment parking areas away from storm water drainage.
10. Improve spill investigations to capture the following information:
    - Detailed description of the cause of the spill (i.e., hydraulic line connection failed, hose burst, hose abrasion).
    - Findings from operator's inspection record (such as reported leaks).

Implementing the Alternative

The team prepared an action plan to implement the selected alternatives. The action plan consists of a three-pronged approach, involving education, maintenance and administrative activities. Implementation is the responsibility of each organization associated with this project and will be coordinated through the project team. The team will meet quarterly to assess progress, identify and implement lessons learned, and quantify the action plan's specified metrics. Annually, an independent person will assess progress in implementing the action plan and to help the team identify necessary plan modifications. Table 4 summarizes the cost of implementing this action plan. The ultimate goal of implementing this action plan is to reduce JCNNM's regulated spill waste generation rate by 70 percent over FY 1999 levels by the end of FY 2002.

Table 4: Action Plan Implementation Costs

Category	First Year Cost	Out Year Costs
JCNNM Labor	$56,305	$18,683
LANL Labor	$18,360	$2160
Equipment	$7,000	$7000
Total	**$81,665**	**$27,843**

Educational Activities Action Plan
Deadline: 9/30/2001
Responsible Party: Jim Stanton

Goal #1: Educate Heavy Equipment Operators, Supervisors and Managers (J. Stanton, R. Perkins, and V. Rodriguez)

Objectives:
- Educate heavy equipment operators and supervisors on the financial impacts of spills.
- Train all operators on initial spill prevention, reporting and response, and provide regular refresher training.
- Train operators to do high-quality, pre-job inspections of the equipment, focusing on leaks.
- Include environmental concerns in pre-job briefings and tailgate meetings, along with the 5-step ISM process.

Goal #2: Educate Project Planners (J. Stanton, R. Perkins, and V. Rodriguez)

Objectives:
- Educate project planners on the financial and environmental impacts of spills, with the goal of improving project planning.
- Include environmental concerns in pre-job briefings and tailgate meetings, along with the 5-step ISM process.

Goal #3: Educate Mechanics and Spill Responders (J. Stanton, R. Perkins, and V. Rodriguez)

Objectives:
- Educate MDHE mechanics to ensure that spills associated with maintenance calls are appropriately reported.
- Educate MDHE mechanics on the need for quick response to reported leaks.
- Educate HENV and MDSG spill responders to more thoroughly investigate the root causes of spills, including talking with mechanics and requesting the most recent inspection forms.

Maintenance Activities Action Plan
Deadline: 4/30/2001
Responsible Party: John Keene

Goal #1: Investigate and replace petroleum-based oils with non-toxic oils (J. Keene and R. Perkins)

Objectives:
- Identify oil performance standards.
- Identify non-toxic oils that meet specified performance standards.
- Test selected non-toxic oils.
- Develop and implement a replacement schedule.

Goal #2: Improve MDHE response to leak reports (J. Keene)

Objectives:
- Evaluate staffing requirements and hire appropriately.
- Develop and implement a leak response time metric.
- Develop and implement incentives for improving maintenance response to reported leaks.

Goal #3: Change aluminum ferrules to steel ferrules (J. Keene)

Objectives:
- Test the resiliency of steel ferrules compared to aluminum ferrules.
- Based on comparative resiliency data, develop and implement a replacement schedule.

Goal #4: Investigate vulnerable hoses and re-route if necessary (J. Keene)

Objectives:
- Ensure vulnerable hoses are identified.
- To the extent possible, ensure that vulnerable hoses are protected from abrasion or snagging.

Goal #5: Put spill kits and recyclable absorbents in every operating piece of heavy equipment (J. Keene)

Objectives:
- Teach operators how to spot and mitigate spills.
- Provide the necessary resources for immediate spill response.

Goal #6: Continue replacing old equipment, as funding becomes available (J. Keene and M. L'Esperance)

Objectives:
- Upgrade equipment to take advantage of design improvements.

Administrative Activities Action Plan
Deadline: 9/30/2001
Responsible Party: Jim Stanton

Goal #1: Establish appropriate regulatory environment (D. Finfrock and J. Stanton)

Objectives:
- Deregulate spill wastes involving non-toxic oils.
- Petition EPA to include bio-based (i.e., vegetable) oils under 40 CFR Part 279.

Goal #2: Improve communication among HENV, MDSG, MDHE, CDDO and UMDO (J. Stanton, R. Perkins, V. Rodriguez, J. Keene and M. L'Esperance)

Objectives:
- Establish a close working relationship among HENV, MDSG, MDHE, CDDO and UMDO personnel.
- Ensure all spills from heavy equipment operations are reported, mitigated and investigated appropriately.

Goal #3: Institute contractual changes (H. Decker, D. Finfrock, J. Stanton and T. Starke)

Objectives:
- Institute a policy of contractual preference to contractors who use non-toxic oils.
- Institute a policy of contractual preference to contractors who are responsible for their own spill waste management.

Goal #4: Improve vehicle management (J. Keene and M. L'Esperance)

Objectives:
- Regularly inspect parked equipment.
- Dedicate an operator for each vehicle to perform daily inspections.
- Return heavy equipment to MDSG or MDHE custody as soon as possible.
- Move all heavy equipment parking areas away from storm water drainage.

Goal #5: Integrate environmental concerns into the 5-step ISM process (J. Stanton, R. Perkins, T. Starke, V. Rodriguez and M. L'Esperance)

Objectives:
- Raise awareness of environmental concerns among line operators.
- Involve personnel in P2 projects.

Goal #6: Improve spill investigations to capture the following information (J. Stanton and V. Rodriguez)

Objectives:
- Develop a detailed description of the cause of each spill.
- Regularly request findings from operator's inspection record.