INNOVATIVE SOFT-SIDED WASTE PACKAGING SYSTEM IMPLEMENTATION AT A SMALL DEPARTMENT OF ENERGY ENVIRONMENTAL RESTORATION/WASTE MANAGEMENT (ER/WM) SITE

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ABSTRACT

Weiss Associates (WA) performs a broad range of environmental restoration/waste management (ER/WM) activities for the U.S. Department of Energy (DOE) at the former Laboratory for Energy-Related Health Research (LEHR), University of California, Davis (UC Davis).

Over the last three years, the LEHR ER/WM program transitioned from a baseline packaging system of steel, 2.7 cubic meter (3.5-cubic yard) B-25 boxes to a 7.0 cubic meter (9.1-cubic yard) soft-sided container (Lift Liner®) system. The transition increased efficiencies in processing, packaging, and storage, and when combined with decreased procurement costs, achieved a $402,000 cost savings (Table I). Additional disposal costs between $128,600 and $182,600 were avoided by minimizing void space. Future cost savings by the end of fiscal year 2003 are projected between $250,640 and $1,003,360.

Table I. LEHR Project Cost Savings Using Soft-Sided Containers Compared to Hard-Sided Containers

Package Class	Package Type	Package Volume (cubic meters)	Cost per Cubic Meter[a]	Waste Volume (cubic meters)	Total Cost
Hard-Side	B-25 Box	2.7	$629	1,529	$962,000
Soft-Side	Super Sack®	0.8	$476	305	$145,600
	Lift Liner®	7.0	$339	1,223	$414,400
Difference (cost avoidance using soft-sided vs. hard-sided containers)					$402,000

[a] Cost per cubic meter includes package cost, delivery, loading, storage and shipping to disposal facility.

The Lift Liner® soft-sided packaging system can be deployed at sites of any size to provide streamlined management and substantial cost savings.

INTRODUCTION

The former Laboratory for Energy-Related Health Research (LEHR) is a 15-acre site located on part of the University of California, Davis (UC Davis) campus (Figure 1). The Atomic Energy Commission and Department of Energy (DOE) sponsored experiments conducted by the University of California at LEHR during the 1960s through the 1980s. These experiments consisted primarily of exposing beagle dogs to strontium-90 and radium–226 to extrapolate the human effects from exposure to low levels of radiation.

The majority of LEHR waste was processed in a Radium/Strontium Treatment System. Effluent from these systems was discharged into the ground through a large leach field and three dry wells. Waste was also buried in the southwest corner of the site in unlined trenches (Southwest Trenches). Pesticides, including chlordane, were used in and near the Dog Pen areas to control fleas.

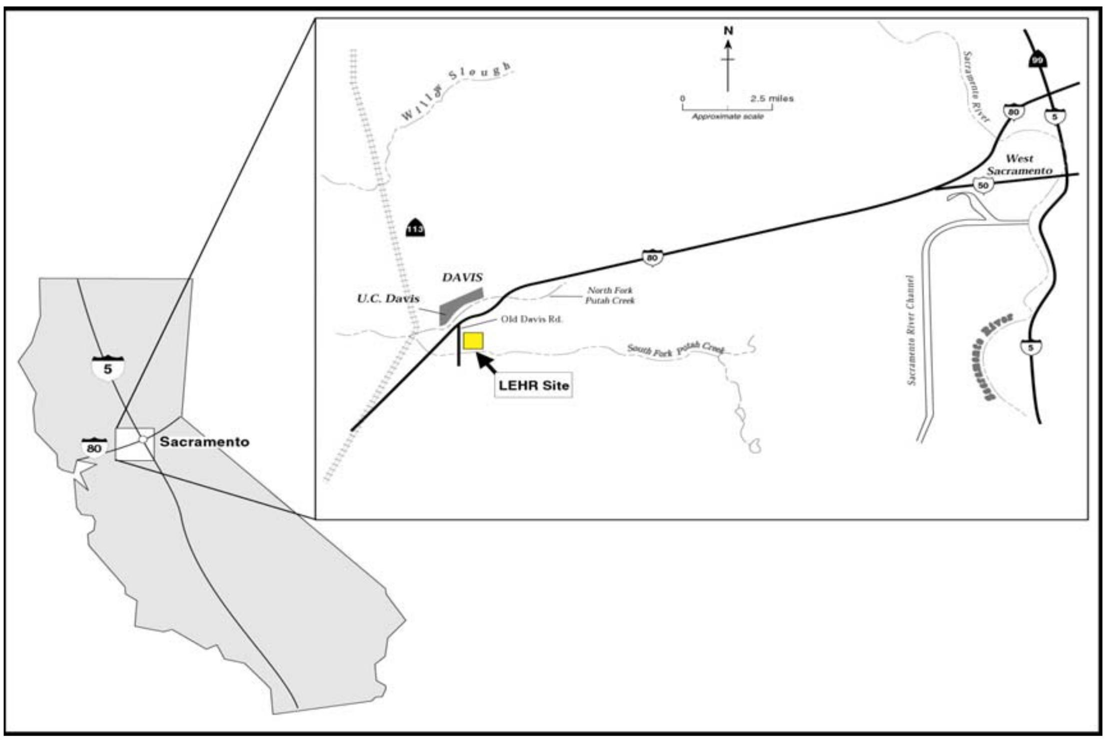

Fig. 1. LEHR Site Location, University of California, Davis

In 1988, pursuant to a Memorandum of Agreement between DOE and the University of California, DOE's Office of Energy Research initiated activities to close out the research program at the site, with the goal of returning the facilities and property to UC Davis after site restoration is complete.

LEHR was added to the U.S. EPA's National Priorities List (NPL) in 1994. WA prepared an Engineering Evaluation/Cost Analysis (EE/CA) in 1998, which recommended removal actions to address the radiological releases from the Radium/Strontium Treatment Systems and burial trenches known as the Southwest Trenches.

Between 1998 and 2000, WA conducted three multi-million dollar removal actions at LEHR that involved excavating more than 1,911 cubic meters (2,500 cubic yards) of radiologically impacted waste from the former Radium/Strontium Treatment Systems and Southwest Trenches. An additional removal action was conducted in 2001 at the former Dog Pens area, generating approximately 1,835 cubic meters (2,400 cubic yards) of waste that is currently being characterized for disposition. LEHR ER/WM waste consists of crushed concrete and asphalt, gravel, cobbles, timber, metal and other miscellaneous debris.

PACKAGING SYSTEM EVALUATION

Three packaging systems have been used at LEHR since 1997 and are evaluated below. Acquisition, delivery, loading, storage and shipping costs were evaluated for each system based on actual rates and crew sizes used during the LEHR removal actions. Advantages and disadvantages are discussed for each system.

For cost analysis purposes the actual rates for loading and handling the three packaging systems were applied to a hypothetical 765 cubic meter (1,000-cubic yard) stockpile of low-level radioactive soil. Production rates vary from project to project depending on waste type (i.e., concrete and rebar, oversized debris, etc.) and specific circumstances. Available site equipment will limit the selection of a packaging system, and affect production rates and costs. For example, LEHR leased equipment, but other projects may have their own material loading and lifting equipment, which would lower the total costs.

Baseline Packaging System – B-25 Boxes

Between 1998 and 2001, the LEHR ER/WM program transitioned from a baseline waste packaging system of steel 2.7 cubic meter (3.5-cubic yard) B-25 boxes to a 7.0 cubic meter (9.1-cubic yard) soft-sided container (Lift Liner®) system. The LEHR project utilized a baseline packaging system of 2.7 cubic meter (3.5-cubic yard) steel boxes in 1998 and 1999 (Figure 2). The boxes are widely used throughout DOE to package low-level waste. The packages are durable, weather-resistant and offer some shielding when packaging radioactive waste and material. The packages are sometimes reusable following refurbishment and certification for safe transport. The boxes are 1.2 meters by 1.2 meters by 1.8 meters (4 ft by 4 ft by 6 ft) and can accommodate an average of 3,628 kilograms (8,000 pounds) of waste depending on the construction and certification.

Fig. 2. Loading a Used B-25 Box Using an Excavator and an End Loader

Costs were calculated for package procurement, delivery, loading, storage, packaging and shipping and are compiled in Table II. The following assumptions were used for the B-25 box cost evaluation and are based on LEHR project experience using this system:

- The total waste volume is 765 cubic meters (1,000 cubic yards) of low-level radioactive waste;
- A new B-25 boxes delivered to the site cost $700;
- The internal volume of a B-25 box is 2.7 cubic meters (94 cubic feet or just less than 3.5 cubic yards);
- B-25 boxes are filled to 90% capacity (2.4 cubic meters or 3.5 cubic yards);
- B-25 boxes are delivered to the site on flat-bed trucks;
- Twenty-eight empty boxes are delivered per truck;
- Two trucks of empty B-25 boxes are off-loaded per day;
- Sixteen B-25 boxes are loaded with waste per 10-hour day (two per hour);
- One loader fills boxes and one loader moves boxes to the storage area;
- The waste packaging crew will work 10-hour days;
- Two spotters are required for waste loading and transportation;
- One Radiation Control Technical (RCT) observes waste packaging and one RCT surveys containers;
- Personal protective equipment (PPE) is changed four times per day;
- Four trucks are loaded with five full boxes for shipment to the disposal facility per day;

- Five working days are required to stage all shipments;
- The waste shipping crew works 10-hour days and consists of one operator and one laborer; and,
- Roundtrip mileage between LEHR and Envirocare of Utah is 2,092 kilometers (1,300 miles).

Table II. Summary of B-25 Waste Packaging System Costs

Activity	Cost
Container procurement	$219,100
Container and equipment delivery	$6,480
Waste loading and storage	$67,360
Waste packaging and shipping	$187,610
Total cost	$480,550
Cost per cubic meter (based on 765 cubic meters)	$629

The B-25 box packaging system performed well, accommodating sharp debris with no package failure. However, packages could not be loaded to full capacity due to weight limitations. Staging was a problem because the site is a small, active research facility with limited storage space. Advantages and disadvantages of the B-25 box packaging system are listed in Table III.

Table III. Advantages and Disadvantages of B-25 Packaging System

Advantage	Disadvantage
No specialized equipment required	Increased unit procurement cost
Sharp debris is acceptable	Void space between 10 and 20 percent
Resistant to weather and pests	Large staging area required for containers
Vapor tight	Not suitable for oversized debris
Radiation shielding	204-250 kilogram (450-550 lb.) package (empty)
Ideal for truck transport	Not intermodal

Between 1997 and 1999 approximately 900 B-25 boxes were loaded with radioactive soil and debris during two removal actions. During the Radium/Strontium Treatment Systems removal action in 1999, a previously unidentified leach field was encountered that required excavation. The projected waste volume for this area was approximately 306 cubic meters (400 cubic yards). The site did not have sufficient inventory of empty B-25 boxes to accommodate the extra waste volume, and was faced with the possibility of demobilizing crews and equipment followed by a costly remobilization when additional waste packages could be deployed on site. Rapid deployment of an alternative packaging system would avoid remobilization and demobilization costs. Super Sacks® were selected to package waste as discussed below.

Transitional Packaging System - Super Sacks®

Soft-sided Super Sacks® (Figure 3) were selected to package the additional waste encountered during the Radium/Strontium Area I removal action. This 0.8-cubic meter (1-cubic yard) package was identified as a viable waste package during an internal pollution prevention assessment conducted by DOE in early 1999.

The Super Sack® is a duffel-top, coated, single-ply polyethylene bag with a plastic six-millimeter inner liner. Four lifting straps are attached to the top of the bag and were utilized by 2,721 kilogram (6,000-lb.) capacity forklifts to keep the bags open when loading and to transport sealed bags to the storage area. The packages were designed to accommodate 0.8 cubic meters (1 cubic yard) and 998 kilograms (2,200 lbs.) of waste.

Fig. 3. Closure of Super Sack® Loaded With Waste Following Weight Measurement.

The Super Sacks® arrived on pallets and required little effort to off-load next to the waste processing area. Packages are stored in warehouses around the country and are readily available. The LEHR Super Sacks® were available from a warehouse 30 miles from the site. This was a key factor in selecting them for use at LEHR.

Costs were calculated for package procurement, delivery, loading, storage, packaging and shipping and are compiled in Table IV. The following assumptions were used for the Super Sack® cost evaluation and are based on LEHR project experience using this system:

- The total waste volume is 765 cubic meters (1,000 cubic yards) of low-level radioactive waste;
- Super Sacks® delivered to the site cost $16 each;
- The internal volume of a Super Sack® is 0.8 cubic meters (27 cubic feet or 1 cubic yard);
- Super Sacks® are filled to 100% capacity;
- A full Super Sack® weighs 998 kilograms (2,200 pounds).

- Super Sacks® are delivered by common carrier;
- The off-loading and staging effort and cost is minimal and not included in this estimate;
- Fifty Super Sacks® are to be loaded with waste per day;
- One skid-steer loader fills Super Sacks®
- Three forklifts alternate holding Super Sacks® during loading and moving to survey/storage areas;
- One RCT observes waste packaging and one RCT surveys containers;
- PPE is changed four times per day;
- The waste loading crew works 10-hour days;
- Five working days are required to stage all shipments;
- Bags will be stockpiled and covered with high-density polyethylene (HDPE) sheeting.
- The waste shipping crew works 10-hour days and consists of one operator and one laborer;
- Sixteen Super Sacks® are loaded into each roll-off container;
- Three trucks carrying one roll-off bin each are shipped per day; and
- Roundtrip mileage between LEHR and Envirocare of Utah is 2,092 kilometers (1,300 miles).

Table IV. Summary of Super Sack® Waste Packaging System Costs

Activity	Cost
Container Procurement	$16,000
Container and Equipment Delivery	-
Waste Loading and Storage	$136,525
Waste Packaging and Shipping	$210,995
Total Cost	$363,520
Cost per cubic meter (based on 765 cubic meters)	$476

The Super Sack® system was successfully used to package LEHR low-level soil, however the package was not suitable for debris as destructive tests at LEHR indicated that the package could not withstand pressure from sharp objects. In addition, the relatively small size required a large number of packages to contain the volumes of waste being generated. Advantages and disadvantages of the Super Sack® system are summarized in Table V:

Table V. Advantages and Disadvantages of Super Sack® Packaging System

Advantage	Disadvantage
No specialized equipment required	Not vapor tight
Low unit procurement cost	Not suitable for sharp and/or oversized debris
Minimal staging area for empty containers	Limited Radiation Shielding
Ideal for small waste streams	Large staging area required for empty and full containers
Intermodal	Not suitable for large waste volumes
Extremely light weight	Increased per package paperwork including surveys and waste tracking data
	Ultraviolet degradation

In 1999, the LEHR site utilized approximately 400 Super Sacks® during the Radium/Strontium Area I removal action. Schedule delays were avoided because the Super Sacks® were on site in less than a week. The Super Sacks® were very inexpensive, but the large quantity of paperwork required to survey and track 400 packages combined with a decreased production rate necessitated finding an alternate packaging system that combined the benefits of both soft-sided and hard-sided containers.

New Baseline Packaging System - Lift Liners®

In 2000, WA staff identified and adopted the 7.0 cubic meter (9.1-cubic yard), Lift Liner® packaging system (Figure 4). The Lift Liner® system has the durable characteristics of the B-25 box and the decreased unit price and beneficial characteristics of the soft-sided Super Sack®. In addition, the package was three times the size of a B-25 box and nearly 10 times the size of a Super Sack®. This packaging system had been deployed with success at Idaho National Engineering and Environmental Laboratory (INEEL, 2001).

The system consists of a two-ply, inner liner and an outer bag of woven and coated polypropylene. The inner liner and outer bags are placed within a loading frame leased from the manufacturer. LEHR specified that loading frames be customized with fork pockets to allow the packages to be transported with a large capacity forklift. In addition, a lifting frame was leased to remove the packages from the loading frame, complete final closure of the outer bags, and place them into storage.

Fig. 4. Excavator Loading Debris into 7.0 Cubic Meter (9.1 Cubic Yard) Lift Liner®

Costs were evaluated and compiled for package procurement, delivery, loading, storage, packaging, and shipping, and are compiled in Table VI. The following assumptions were used for this cost evaluation and are based on LEHR project experience using this system:

- The total waste volume is 765 cubic meters (1,000 cubic yards) of low-level radioactive waste;
- Each Lift Liner® has a 10,886 kilogram (24,000 lb.) weight capacity and is filled to 6.5 cubic meters (8.5 cubic yards);
- Twelve Lift Liners® are loaded per day;
- One loader fills Lift Liners® and one large forklift stages lifting frames and transports loaded containers to the storage area;
- The waste loading crew works 10-hour days and consists of two operators and three laborers;
- One RCT observes waste packaging and one RCT surveys containers;
- PPE is changed four times per day;
- Lift Liners® are covered and sealed with HDPE;
- Two Lift Liners® are loaded into each end-dump truck based on weight limitations;
- One 11,793 kilogram (13-ton) forklift is used to load Lift Liners® into end-dump trucks;
- Six trucks are shipped per day;
- One RCT is required for shipping;
- The waste shipping crew works 8-hour days and consists of one operator and 2 laborers;
- Waste is stockpiled and does not require processing;
- Waste packages are direct-loaded into end-dump trucks on day of shipment and no staging is required; and,
- Round trip mileage between LEHR and Envirocare is 2,092 kilometers (1,300 miles).

Table VI. Summary of Lift Liner® Waste Packaging System Costs

Activity	Cost
Container procurement	$45,430
Container and equipment delivery	$3,190
Waste loading and storage	$47,040
Waste packaging and shipping	$163,380
Total cost	$259,040
Cost per cubic meter (based on 765 cubic meters)	$339

The Lift Liner® proved to be a very flexible packaging system. Deployment of two loading frames and the lifting frame allowed continuous excavation and waste loading. Production rates increased substantially and unit production costs decreased compared to the B-25 box. The large package size also resulted in efficiencies in surveying and waste tracking, associated paperwork was reduced by 60% compared to the B-25 boxes and almost 90% compared to the Super Sack®. Advantages and disadvantages of the system are summarized in Table VII.

Table VII. Advantages and Disadvantages of New Baseline Packaging System – Lift Liners®

Advantage	Disadvantage
Decreased unit cost	Specialized equipment required
Bulk package	Not suitable for small waste volumes
Simple system	No vapor barrier
Conforms to waste	Selective loading of sharp debris
Lightweight fabric	Limited radiation shielding
Minimal staging area for empty containers	Ultra violet degradation (over 1 year)
Accommodates oversized and sharp debris	Pest damage (i.e. rodents)
Easily repaired or repackaged	Puncture resistant, not puncture proof

During 2000 and 2001, the LEHR site used over 200 Lift Liners® to package debris such as crushed concrete, crushed asphalt, steel reinforcing bar (rebar), and other building debris (i.e., glass, lumber, roofing materials, etc.) with only three package failures which were easily repaired with patching materials or by over-packing in another Lift Liner®. The Lift Liner® packaging system was adopted as the new baseline packaging system based on the advantages described above and the cost savings described below.

PACKAGE SYSTEM COST COMPARISON

Unit costs were calculated and compiled for each package type and shown in Table VIII. Package procurement costs are substantially lower for soft-sided containers compared to the hard-sided containers. Costs per cubic meter for the Lift Liner® were $137 less than the Super Sack® and $290 less than the B-25 Box. Costs per cubic meter are based on actual production rates and unit costs from four removal actions.

Table VIII. Cost Comparison Between B-25 Box, Super Sack® and Lift Liner® Packaging Systems Based on 765 Cubic Meters of Waste

Activity	Package Type		
	New B-25	Super Sack®	Lift Liner®
Container procurement	$219,100	$16,000	$45,430
Container and equipment delivery	$6,480	-	$3,190
Waste loading and storage	$67,360	$136,525	$47,040
Waste packaging and shipping	$187,610	$210,995	$163,380
Total cost	$480,550	$363,520	$259,040
Cost per cubic meter (based on 765 cubic meters)	$629	$476	$339

LEHR realized a 50% reduction in procurement and labor costs. A similar comparison completed by INEEL showed an 80% reduction of procurement and labor costs using the soft-sided containers compared to the hard-sided steel and wood packages that they previously used (INEEL, 2001).

PROJECT COST ANALYSIS

Cost Avoidance

Between 1999 and 2002, the LEHR project achieved $402,000 in cost savings using soft-sided containers compared to hard-sided containers (Table IX). Actual volumes packaged are presented for the Super Sack® and Lift Liner® packaging systems. The packages and costs associated with the B-25 boxes are based on assumed quantities if the project had continued to utilize that packaging system. Unit prices include package procurement through waste transportation on a per cubic meter basis and do not include tipping fees at the disposal facility.

Table IX. Comparison of Packaging Costs and Cost Avoidance for LEHR Packaging Systems

Package Class	Package Type	Package Volume (cubic meters)	Cost (per cubic meter)	Waste Volume	Total Cost
Hard-Sided	B-25 Box	2.7	$629	1,529	$962,000
Soft-Sided	Super Sack®	0.8	$476	305	$145,600
	Lift Liner®	7.0	$339	1,223	$414,400
Difference (cost avoidance using soft-sided vs. hard-sided containers)					$402,000

Secondary Cost Avoidance

Soft-sided containers conform to the packaged waste, optimizing container loading by minimizing void space, which translates into the preservation of valuable landfill space and disposition cost avoidance. Void space in traditional packages (drums, steel boxes, etc.) is between 10% and 20% depending on the size, shape and density of the waste. The LEHR site preserved 153 cubic meters (200 cubic yards) of disposal facility capacity and avoided disposal costs between $128,600 and $182,600(Tables X) using soft-sided containers.

Table X. Void Space and Disposition Costs Comparison between Lift Liner® System and B-25 Boxes

Package Type	Packaged Waste	Package Void Space (%)	Total Void Space (cubic meters)	Disposition cost for Soil Void Space[a]	Disposition cost of Debris Void Space[a]
B-25 Box	1,529	10	153	$128,600	$182,600
Super Sack®	305	0	0	$0	$0
Lift Liner®	1,223	0	0	$0	$0
Difference (B-25 compared to Lift Liner®)				$128,600	$182,600

[a] Disposition cost includes package system costs discussed above plus disposal facility tipping fee specific to soil or debris.

FUTURE APPLICATIONS

The LEHR project generated approximately 612 cubic meters (800 cubic yards) of low-level radioactive debris (crushed concrete, metal and wood) during 2001 that is currently stockpiled for eventual packaging and disposal. If the B-25 box packaging system were utilized, the project cost for packaging and low-level radioactive debris disposal would be approximately $730,000. However, utilizing the Lift Liner® system, the project will realize a cost savings of approximately $177,600. The reduction of void space will avoid the disposal of 61.2 cubic meters (80 cubic yards) (10% of 612 total cubic meters of waste) of void space as low-level waste, saving $73,040 in packaging and disposal costs.

The LEHR site has an additional 1,835 cubic meters (2,400 cubic yards) of debris (asphalt and gravel) that may be classified as low-level radioactive waste. If this debris were packaged using the B-25 system, packaging and disposal costs of $2,192,000 would be incurred compared to $1,658,400 with the Lift Liner® system, a $533,600 cost savings. The elimination of void space will avoid the disposal of 183.5 cubic meters (240 cubic yards) (10% of 1835 total cubic meters of waste) of void space as low-level waste, saving $219,120 in packaging and disposal costs.

The LEHR site is evaluating other bulk packaging and transportation options for these wastes/materials. These options include the use of other intermodal containers, lined end-dump trucks, and rail transportation, which may reduce packaging and transportation costs further.

CONCLUSIONS

Over the last three years, the LEHR ER/WM program transitioned from a baseline packaging system of steel, 2.7 cubic meter (3.5-cubic yard) B-25 boxes to a 7.0 cubic meter (9.1-cubic yard) soft-sided container (Lift Liner®) system. The transition increased efficiencies in processing, packaging, and storage, and when combined with decreased procurement costs, achieved a $402,000 cost savings. Additional disposal costs between $128,600 and $182,600 were avoided by minimizing void space. Future cost savings by the end of fiscal year 2003 are projected between $250,640 and $1,003,360.

The Lift Liner® soft-sided packaging system can be deployed at sites of any size to provide streamlined management and substantial cost savings.

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ACRONYMS

Co-60	cobalt-60
DOE	United States Department of Energy
EPA	Environmental Protection Agency
ER/WM	environmental restoration/waste management
HDPE	high-density Polyethylene
INEEL	Idaho National Engineering and Environmental Laboratory
Lb	pound
LEHR	Laboratory for Energy-Related Health Research
LLW	low-level waste
Mil	millimeter
PPE	personal protective equipment
Ra-226	radium-226
RCT	Radiological Control Technician
Sr-90	strontium-90
UC Davis	University of California, Davis
UV	ultraviolet
WA	Weiss Associates

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