



MONTANA DEPARTMENT OF TRANSPORTATION

Environmental Services

Memorandum

To: Distribution

From: Eric Stimson
Environmental Services Bureau

Date: May 27, 2005

Subject: Update: Snowplow Sidecast Experiment

On March 14, 2005, Montana Department of Transportation (MDT) Lewistown Maintenance personnel conducted the second “Snowplow Sidecast” experiment at the Lewistown airport facility, near the MDT Lewistown Maintenance Division headquarters. This experiment was first conducted on Dec. 8, 2003, for the purpose of discovering how much road sand is plowed off the road surface by a snowplow during winter snow- plowing operations, and how far from the edge of the road that sand is carried by the plowed snow. The March 2005 experiment adds to the base of knowledge that MDT began compiling in 2003. This memorandum summarizes the results of the March 2005 experiment and compiles that information with the results of the December 2003 experiment.

The Snowplow Sidecast experiment was designed jointly by the MDT Environmental Services Bureau and by personnel from the MDT Lewistown Maintenance Area, with assistance from MDT Maintenance headquarters personnel, the Montana Office of Public Instruction, and the Western Transportation Institute. The March 2005 experiment design and procedures were essentially the same as the December 2003 design and procedures, and are recapped (and amended where appropriate) in this memorandum.

Experiment Design and Procedure

Test Track A test track for the experiment was prepared on a paved portion of the Montana Driver Education Facility at the old Lewistown Airport. Since part of the experiment seeks to understand the role of plowing speeds on the distance that snow/sand is cast during snowplowing operations, collection mats were laid out for snowplowing at 25 mph, 35 mph, and 45 mph (see Figure 1). Strips of plastic artificial grass were cut and installed for the sand collection mats, each mat measuring 3 feet wide by 10 feet long. The mats were placed end-to-end, out to a total composite distance of 40 feet from the edge of the plowed roadway.

Crosswind Effects To account for the effects of crosswinds on the experimental data, collection strips were set out on both sides of the roadway, which was plowed going both directions (see Figure 1). The results from both collection strips for each of the three speeds were combined and averaged, eliminating the crosswind factor. Once the test track was prepared (see below), the snowplow accelerated northbound to 45 mph and plowed the roadway adjacent to the “45 mph” collection strip, then decelerated to 35 mph adjacent to the

“35 mph” strip, then decelerated again to 25 mph adjacent to the “25 mph” strip. The plow then continued on, turned around, accelerated southbound to 45 mph and repeated the procedure going in the opposite direction.

Track Preparation and Sand Loading In order to determine what percentage of the sand applied to the roadway is cast from the roadway and how far that sand is cast, the amount of sand applied to the roadway had to be determined. To establish that known amount, the sand-spreading mechanism on the snowplow was calibrated before the experiment in the following way: An area measuring three feet in the direction of travel by twelve feet wide (one traffic-lane width) was marked on the pavement (an area containing four square yards). The sand-delivery mechanism was set and road sand was applied to the roadway by the snowplow traveling at 35 mph. The sand that landed on the 3' by 12' area was then collected and weighed. This procedure was done four times and an average weight was determined for the four passes. This average weight was divided by four to arrive at the average amount of sand applied per square yard to the test track. When the experiment took place, the same application speed and settings were used to spread sand on the track, resulting in a measured sand application rate of 2.12 pounds of sand per square yard of pavement on the test track. Appendix 1 describes this procedure in more detail.

Plowing Procedure

When a snowstorm dropped two inches of wet snow on the test track on the morning of March 14, 2005, the experiment began. The snowplow drove over the track several times (with the snowplow blade up) to make a snowpacked roadway. At 11:43 AM, the snowplow applied sand to the track at the pre-measured rate of 2.12 pounds per square yard. Once the test track was prepared in this way, the track was plowed twice in each direction, at the three specified speeds. At 11:55 AM, the track was plowed a third time in both directions, resulting in a roadway with very little snow left on it. The snow was allowed to melt off the mats, and at 7:40 AM on March 22, the MDT Lewistown maintenance crew collected the mats and transported them to the MDT Lewistown materials laboratory. See Appendix 2 for details of the plowing conditions and procedures during the experiment.

Collection Mat Handling Before the experiment took place, each 3 X 10 ft collection mat was dried, marked and weighed, together with its dried and marked canvas bag, and that initial weight was recorded. After the snow/sand was plowed off the test track, each collection mat was picked up and placed in its corresponding canvas bag, taking care not to spill any snow/sand in the process. The bags with the mats inside were sealed and dried, the final drying taking place inside a hot air drier in the Lewistown Maintenance facility's laboratory. When dry, each pre-weighed mat and bag were weighed again, the difference in weight corresponding to the weight of sand that was plowed onto that mat during the experiment. The sand collected by each mat was then emptied onto a pan and sieve analyses were performed to determine the size fractions collected by each mat. See Appendix 3 for a description of the materials and data collection procedures used in the experiments. (The sieve analysis data has not yet been compiled as of the date of this report.)

Experiment Results

Tables 1 and 2 summarize the results of the 2005 and 2003 experiments, respectively. Figures 2 and 3 display the results for the two experiments graphically. For the purposes of the experiment, it was assumed that the snow/sand mixture on each linear yard of roadway (in the

direction of travel) is completely plowed off to the right side of the road, and an equivalent one-yard wide area beside the road receives, on average, the amount of sand applied to a yard of roadway. Since the plowed lane is four yards wide (a 12-foot lane), each linear yard of roadway can contribute up to 8.48 pounds of sand (4 times 2.12 pounds per yard) to the collection area located to the right of the direction of the snowplow.

Of the total possible 8.48 pounds of sand received by the collection mats (from zero out to forty feet at any location), the difference between 8.48 pounds and the amount of sand weighed on the collection mats represents the sand that remained on the test track after the plowing was completed.

Combining the northbound and southbound mats for each speed (shaded set of numbers on Table 1), the following results for the 2005 experiment were observed:

At 25 mph

- 74% of the sand remained on the roadway after the snow was plowed off;
- 12% of the applied sand was cast zero to ten feet from the edge of the road;
- 7% of the applied sand was cast ten to twenty feet;
- 5% of the sand was cast twenty to thirty feet; and
- 2% of the applied sand was cast thirty to forty feet.
- No snow or sand from the plowing operation was observed beyond forty feet from the edge of the plowed road.

At 35 mph

- 68% of the sand remained on the roadway after the snow was plowed off;
- 19% of the applied sand was cast zero to ten feet from the edge of the road;
- 8% of the applied sand was cast ten to twenty feet;
- 3% of the sand was cast twenty to thirty feet; and
- 2% of the applied sand was cast thirty to forty feet.
- No snow or sand from the plowing operation was observed beyond forty feet from the edge of the plowed road.

At 45 mph

- 69% of the sand remained on the roadway after the snow was plowed off;
- 12% of the applied sand was cast zero to ten feet from the edge of the road;
- 11% of the applied sand was cast ten to twenty feet;
- 6% of the sand was cast twenty to thirty feet; and
- 2% of the applied sand was cast thirty to forty feet.
- No snow or sand from the plowing operation was observed beyond forty feet from the edge of the plowed road.

Comparison of the 2005 Experiment Results with the 2003 Experiment Results

- Wet snow and slush characterized the snow conditions in the 2005 experiment, compared to a drier, more powdery snow in the 2003 experiment.
- Snow and sand were cast farther in the 2005 experiment (wet snow conditions) than during the 2003 experiment (dry snow conditions). In 2003, no snow/sand was found

farther than 20 feet from the edge of plowed road; in 2005, between 5% and 8% of the sand applied to the roadway was found on the collection mats between 20 feet and 40 feet from the edge of the plowed road surface.

- During the 2003 experiment, an average of 76% of the applied road sand stayed on the roadway after the snow was plowed off (ranging from 53% to 90% for the three plowing speeds). In the 2005 experiment, an average of 70% of the applied road sand stayed on the roadway after the plowing operations ceased (ranging from 68% to 74% for the three speeds).
- In the 2003 experiment, 100% of the sand applied to the roadway either stayed on the roadway or landed within 20 feet of the edge of the plowed road. In the 2005 experiment, an average of 93% of the sand applied to the roadway either remained on the roadway or landed within 20 feet of the edge of the plowed road.
- After the 2003 experiment, it appeared that the slower snowplow speeds resulted in more of the sand being plowed off the road surface compared to the higher snowplow speeds (47% of the sand plowed off at 25 mph compared to 16% and 10% at 35 mph and 45 mph, respectively). That relationship was not seen in the 2005 results (26%, 32% and 31% of the sand plowed off at 25 mph, 35 mph, and 45 mph, respectively).

Discussion of Results of the Two Experiments

After two repetitions of the snowplow sidecast experiment (2003 and 2005), these conclusions regarding the behavior of road sand in the snowplowing environment can be identified:

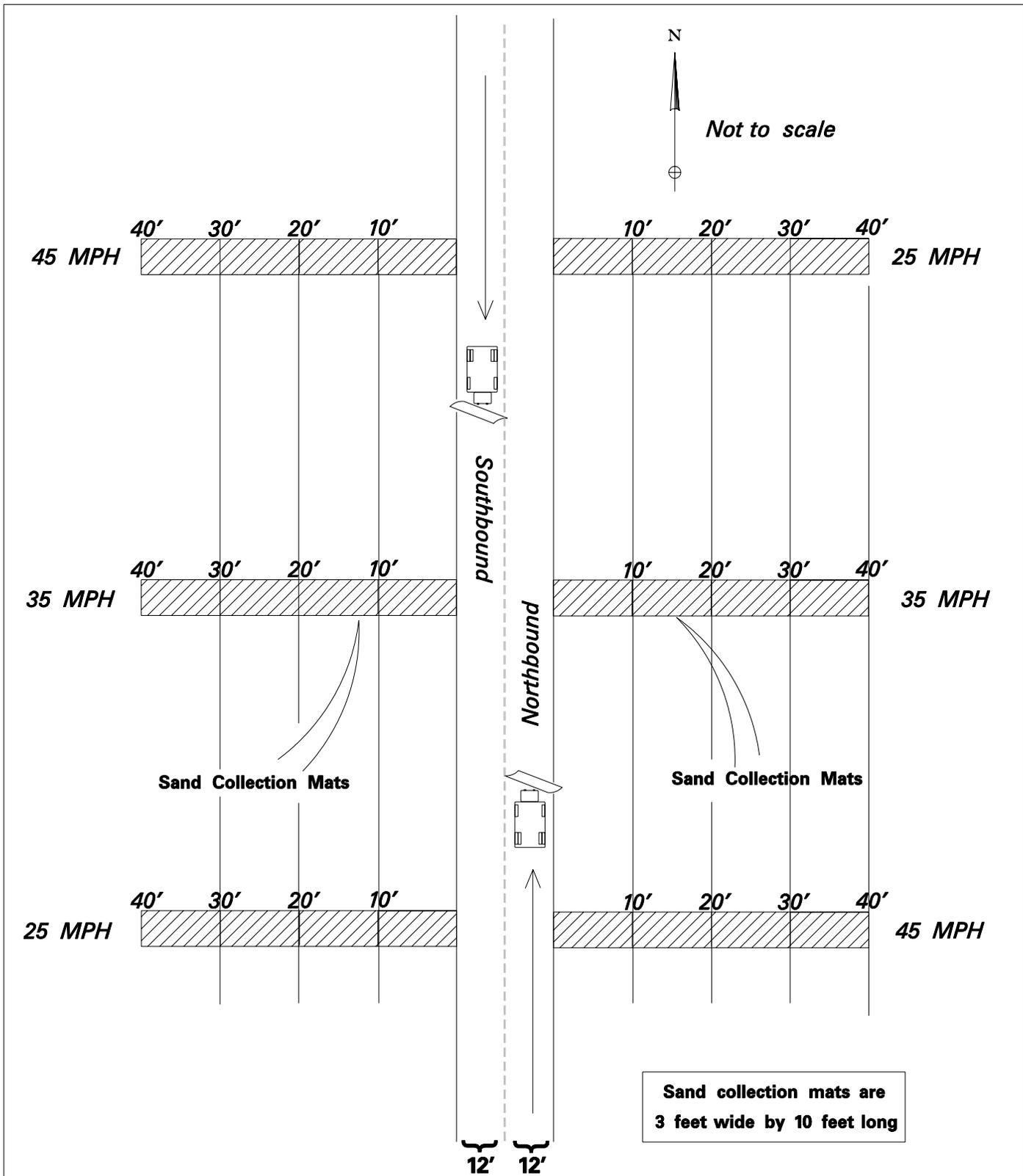
1. In the absence of normal highway traffic, most of the sand applied to the roadway during winter sanding/plowing operations stays on the roadway. The two experiments indicate that an average of 73% of the sand applied to the roadway stays on the roadway after plowing operations have ceased. Under normal highway conditions, most of the sand left on the roadway is ultimately blown by traffic or wind or washed by water to the edge of the road, where it either enters a roadside ditch or accumulates on the shoulder.

While it may seem odd that such a high percentage of traction sand applied to the road is not plowed off by the snowplow, several lines of evidence support this conclusion: (a) A significant quantity of sand was observed on the test track after the plowing experiment was completed. (b) Salt in the sand causes the salt-sand mixture to melt the snow rapidly, allowing the sand to migrate downward to the road surface where it is more difficult for the plow to pick up and cast off the road; and (c) The snow/sand mixture is carried along the roadway in front of the snowplow blade for a significant distance before it is cast to the side, allowing many of the dense sand particles to reach the road surface before they can be plowed off the road with the snow. Future studies should be directed at quantifying this tendency of sand to stay on the roadway.

2. Most of the sand that is plowed off the roadway during snowplowing activities is cast 20 feet or less from the edge of the plowed roadway. An average of 24% of the road sand that is applied to the road surface lands within 20 feet of the snowplow. For most highways, this first 20 feet from the edge of the plowed pavement is part of the ditch, shoulder, or fill slope portions of the engineered roadway. Vegetation of the shoulders and fill slopes and the use of ditch blocks in the ditches can be successfully employed to trap or stabilize the road sand that is plowed onto these areas.
3. A small percentage of the sand applied to the roadway during plowing/sanding operations is cast farther than 20 feet, onto the area beyond the shoulder and possibly beyond the highway fill slope. Averaging the results of the two sidecast experiments, approximately 3% of the road sand applied to the roadway is cast by the snowplow more than 20 feet.
4. Snowplow speed does not appear to be a significant factor in determining how far sand is cast during plowing operations, especially beyond 20 feet. The 2005 experiment resulted in 7%, 5%, and 8% sand accumulation beyond 20 feet at plowing speeds of 25, 35, and 45 mph, respectively. (The 2003 experiment resulted in no sand cast beyond 20 feet, regardless of snowplow speed); and
5. Snow moisture has an effect on how far the snow/sand mixture is cast by the snowplow. No sand was cast beyond 20 feet when plowing dry snow (2003), while between 5% and 8% of the sand applied to the wet snow in the 2005 experiment was cast from 20 to 40 feet from the edge of the plowed roadway.

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MONTANA DEPARTMENT OF TRANSPORTATION

Figure 1
SNOWPLOW SIDECAST EXPERIMENT
Schematic Diagram

May 20, 2005	MDT Lewistown Maintenance Div. OPI Lewistown Facility	Fergus Co., MT
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Table 1

**MDT SNOWPLOW SIDECAST EXPERIMENT
SPRING, 2005**

Plowing Speed / Lane	Total pounds of sand applied (1)	Pounds sand left on the road (2)	lb sand on mat 0'-10' (3)	lb sand on mat 10'-20' (3)	lb sand on mat 20'-30' (3)	lb sand on mat 30'-40' (3)						
Northbound												
25 mph	8.48	6.58	0.805	0.558	0.381	0.150						
35 mph	8.48	6.86	0.586	0.714	0.209	0.108						
45 mph	8.48	5.37	0.966	1.213	0.675	0.256						
Southbound												
25 mph	8.48	5.97	1.327	0.562	0.456	0.168						
35 mph	8.48	4.73	2.641	0.615	0.254	0.245						
45 mph	8.48	6.33	1.124	0.677	0.269	0.077						

Combined Results: Northbound Lane plus Southbound Lane												
Plowing Speed	Total pounds of sand applied	Pounds sand left on the road	lb sand on mat 0'-10'	lb sand on mat 10'-20'	lb sand on mat 20'-30'	lb sand on mat 30'-40'		Percent sand left on road	Percent sand cast 0' to 10'	Percent sand cast 10' to 20'	Percent sand cast 20' to 30'	Percent sand cast 30' to 40'
25 mph	16.96	12.55	2.132	1.120	0.837	0.318		74%	12%	7%	5%	2%
35 mph	16.96	11.59	3.227	1.329	0.463	0.353		68%	19%	8%	3%	2%
45 mph	16.96	11.70	2.090	1.890	0.944	0.333		69%	12%	11%	6%	2%

- (1) " Total pounds of sand" is based on a rate of 2.12 lb of road sand applied to each square yard of roadway (see Appendix 1). Each collection mat is 3 feet wide. Assume each 3-foot wide mat receives the amount of sand found on 3 feet of roadway. A 3-foot length of a 12-foot wide lane is 4 sq yards and receives 8.48 lb road sand.
- (2) "Pounds sand left on the road" is 8.48 lb (per lane), minus the sand measured on the collection mats at that speed and location.
- (3) Weight of captured sand measured on each collection mat

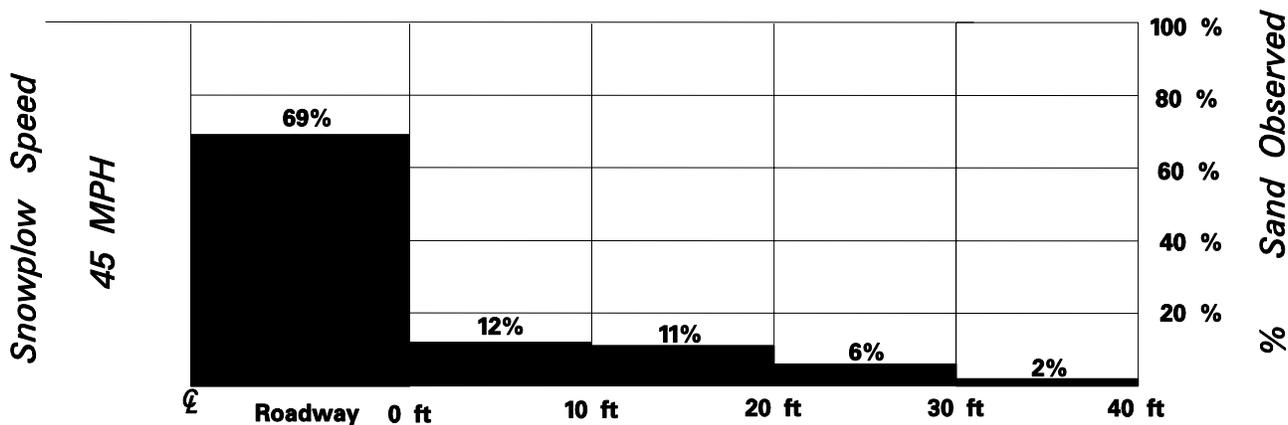
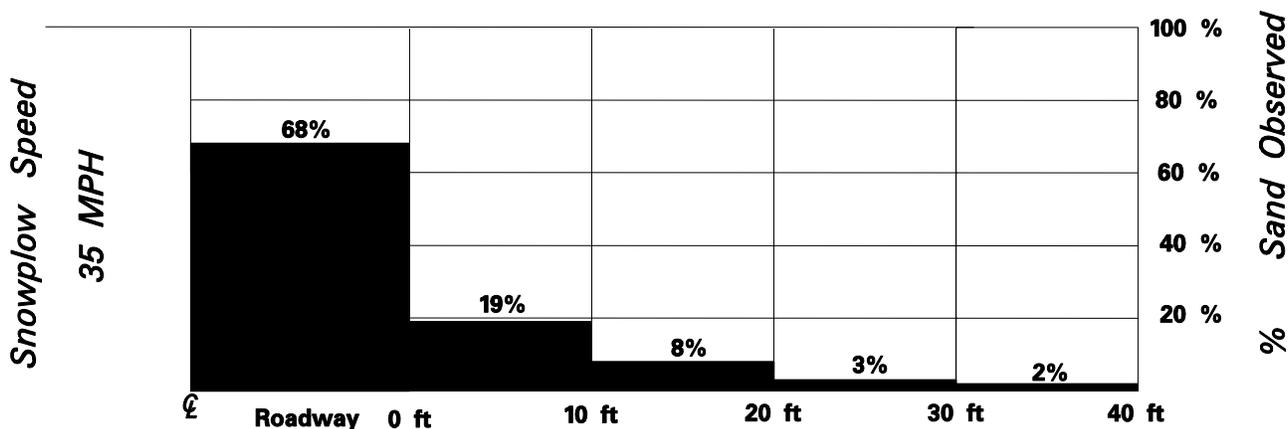
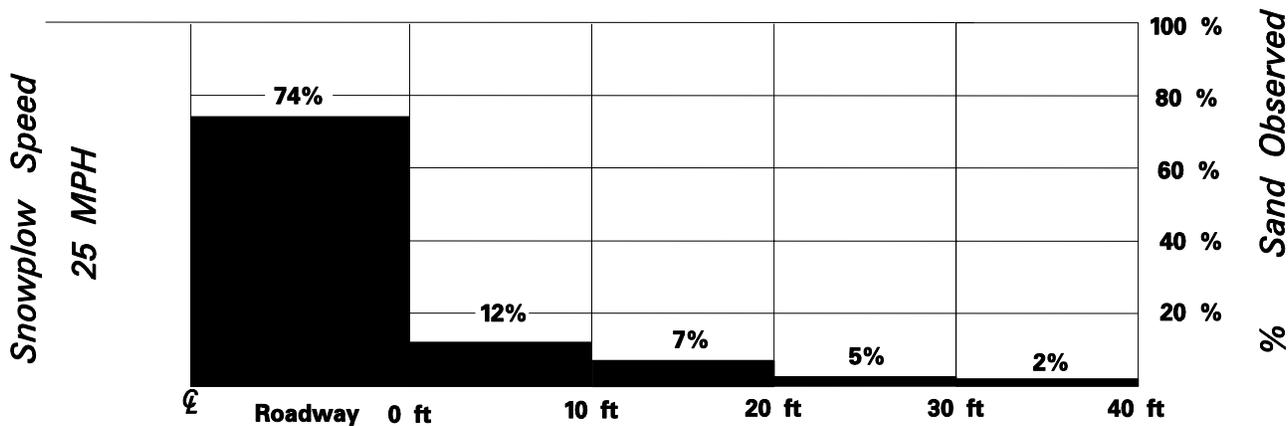
Table 2

**MDT SNOWPLOW SIDECAST EXPERIMENT
DECEMBER, 2003**

Plowing Speed / Lane	Total pounds of sand applied (1)	Pounds sand left on the road (2)	lb sand on mat 0'-10' (3)	lb sand on mat 10'-20' (3)	lb sand on mat 20'-30' (3)	lb sand on mat 30'-40' (3)							
Northbound													
25 mph	8.48	1.647	6.394	0.439	0	0							
35 mph	8.48	6.441	1.940	0.099	0	0							
45 mph	8.48	7.611	0.627	0.242	0	0							
Southbound													
25 mph	8.48	7.286	1.194	0	0	0							
35 mph	8.48	7.787	0.565	0.128	0	0							
45 mph	8.48	7.617	0.438	0.425	0	0							

Combined Results: Northbound Lane plus Southbound Lane													
Plowing Speed	Total pounds of sand applied	Pounds sand left on the road	lb sand on mat 0'-10'	lb sand on mat 10'-20'	lb sand on mat 20'-30'	lb sand on mat 30'-40'		Percent sand left on road	Percent sand cast 0' to 10'	Percent sand cast 10' to 20'	Percent sand cast 20' to 30'	Percent sand cast 30' to 40'	
25 mph	16.96	8.933	7.588	0.439	0	0		53%	45%	2%	0%	0%	
35 mph	16.96	14.228	2.505	0.227	0	0		84%	15%	1%	0%	0%	
45 mph	16.96	15.228	1.065	0.667	0	0		90%	6%	4%	0%	0%	

- (1) " Total pounds of sand" is based on a rate of 2.12 lb of road sand applied to each square yard of roadway (see Appendix 1). Each collection mat is 3 feet wide. Assume each 3-foot wide mat receives the amount of sand found on 3 feet of roadway. A 3-foot length of a 12-foot wide lane is 4 sq yards and receives 8.48 lb road sand.
- (2) "Pounds sand left on the road" is 8.48 lb (per lane), minus the sand measured on the collection mats at that speed and location.
- (3) Weight of captured sand measured on each collection mat



Montana Department of Transportation

Figure 2

Snowplow Sidecast Experiment: March 2005

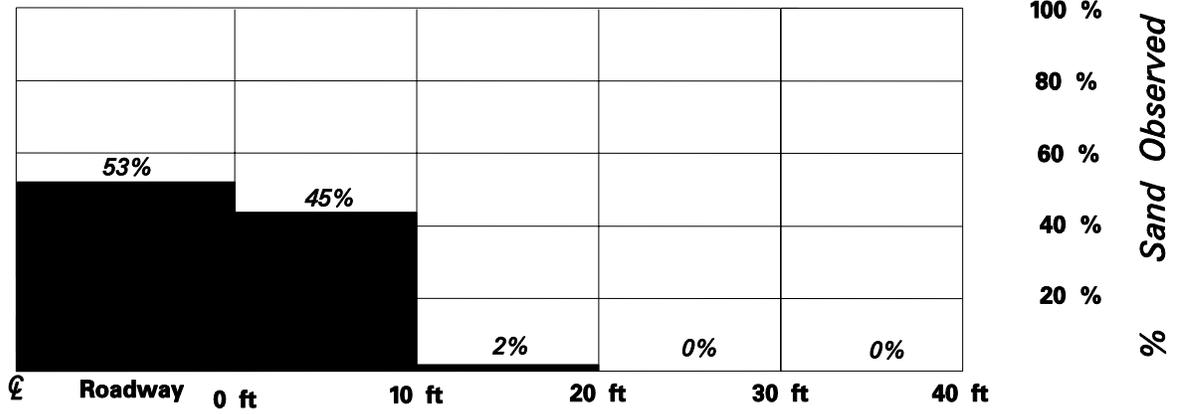
Sand Quantities Observed on the Roadway and out to 40 Feet Distance

May 20, 2005

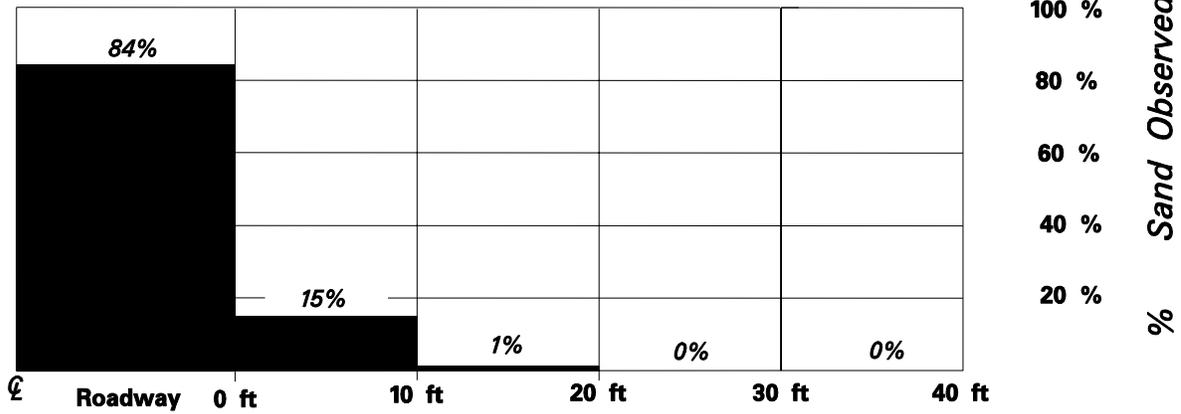
MDT Lewistown Maintenance Division
OPI Lewistown Facility

Fergus County, Montana

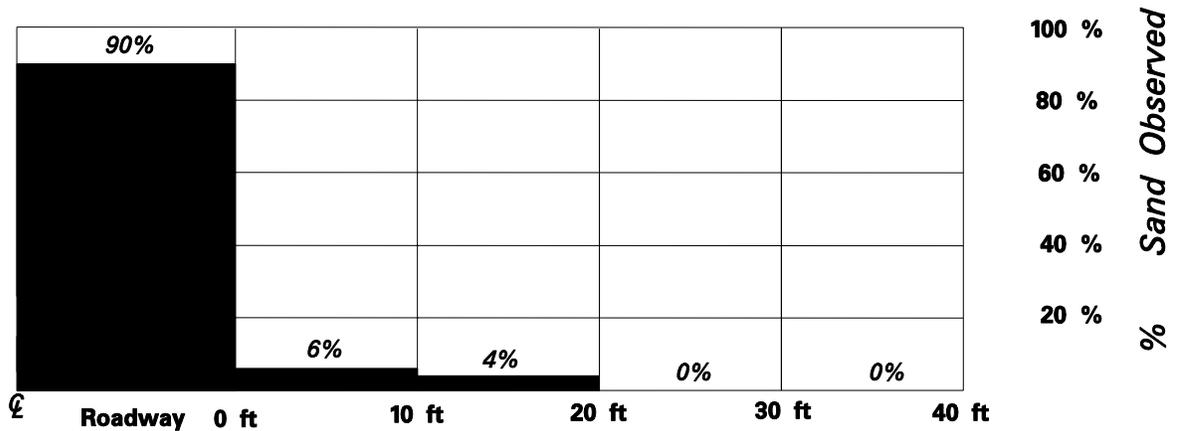
**Snowplow Speed
25 MPH**



**Snowplow Speed
35 MPH**



**Snowplow Speed
45 MPH**



Montana Department of Transportation

Figure 3 Snowplow Sidecast Experiment: December 2003

Sand Quantities Observed on the Roadway and out to 40 Feet Distance

Dec. 28, 2004

MDT Lewistown Maintenance Division
OPI Lewistown Facility

Fergus County, Montana

APPENDIX 1

Notes on Experimental Procedures and Quantities

MDT Lewistown Maintenance Supervisor K. Schanz calculated that 2.12 pounds of sand per square yard was applied to test track before plowing. To arrive at this loading figure, four marked areas, each measuring 1 yard by 4 yards (4 square yards each), were laid out on the test track. Sand was applied by the snowplow (at 35 mph) at the same setting used during the experiment. The four areas received sand, which was collected and weighed. The 4 areas received 2.11 lb, 2.03 lb, 1.90 lb, and 2.38 lb, for an average of 2.105 lb per marked area. Each marked area is 4 square yards, resulting in an application rate of 0.53 lb per square yard per application. At the time of the experiment, the snowplow made four applications to the test track, resulting in a total sand load of 2.12 pounds of road sand applied to each square yard of the track.

The collection mats measure 3 feet wide by 10 feet long and were laid out end-to-end out to a distance of 40 feet from the plowed lane (see Figure 1). Since the snow and sand from the entire 12-foot wide lane is plowed off by the snowplow, the sand received by a 3-foot wide collection mat is equivalent to the sand received by a 3-foot by 12-foot section of roadway (minus the sand that never leaves the roadway).

A 3-foot by 12-foot section of roadway (4 square yards) receives 8.48 pounds of sand (4 square yards times 2.12 pounds per square yard). Two 12-foot lanes (northbound and southbound) receive 16.96 pounds of sand. If the sand measured on the collection mats at a particular location (e.g. all the 35 mph mats for both travel directions out to 40 feet from the roadway) were to add up to 16.96 pounds, 100% of the road sand would be accounted for on the mats. Anything less than 16.96 pounds represents sand that remains on the roadway that was not plowed off during the experiment.

APPENDIX 2: EXPERIMENT DATA RECORDING SHEETS

<p><u>LEWISTOWN SNOWPLOW EXPERIMENT</u> <u>DATA RECORDING SHEET</u> DECEMBER 8, 2003</p>	
Name: <u>Ken Schanz</u>	Date: <u>Dec. 8, 2003</u>
	Time: <u>10:28 AM</u>
Comments:	
2-3 inches of wet snow. Removed plastic. Drive on snow to make snowpack	
10:40 AM: Put on sand at 4 passes	
10:45 AM: Plow road at 2 passes. 12:16 PM: Made 1 more pass with snowplow	
12:21 PM: Started picking up mats. 1st and 2nd pass with plow at mat "C", the wind from plow lifted end of mat nearest road.	
Weather Conditions: Cloudy, heavy fog.	
Temperature: 17 degrees F	Relative Humidity:
Wind Direction: Calm	From the (NA)
Wind Speed: Calm	

<p><u>LEWISTOWN SNOWPLOW EXPERIMENT</u> <u>DATA RECORDING SHEET</u> MARCH 14, 2005</p>	
Name: <u>Ken Schanz</u>	Date: <u>Mar. 14, 2005</u>
	Time: <u>11:43 AM</u>
Comments:	
Two inches of wet snow - sanded at four passes	
11:55 AM: Plowed off snow	
March 22, 2005: 7:40 AM Picked up mats and took to lab	
Weather Conditions: Partly cloudy	
Temperature: 30 degrees F	Relative Humidity:
Wind Direction: Light	From the West
Wind Speed: Less than 5 mph	

APPENDIX 3

MATERIALS

AND

DATA COLLECTION PROCEDURES

Materials

- 720 sq ft of plastic “grass mat”, cut into 24 strips, each measuring 3’ x 10’ (30 sq ft);
- asphalt nails to nail the grass strips to the pavement;
- Enough used metal signs to cover all the mats until the time to run the experiment; and
- 24 cloth bags, big enough to put in a 3’ x 10’ “grass” strip with its snow-sand load on it.

Data Collection Procedures

- Weigh each 3’ x 10’ grass strip (“sand collection mat”) along with its cloth bag. Label each bag and corresponding strip (e.g. “Northbound, 45 mph, 0-10 ft”) and record the dry, “unloaded” weight of the bag and collection mat.
- Nail each 3’ x 10’ collection mat to the pavement, perpendicular to the roadway, end to end, making a composite strip 3’ wide by 40’ long (see Figure 1);
- After the snowplow has plowed off the snow-sand mixture, collect each 3’ x 10’ mat and put the mat (with its snow-sand load) in its corresponding bag. It is acceptable to wait for some or all of the snow to melt before collecting the mats, providing the snow is not drifting. Efforts were made not to lose any of the sand on the mat when rolling it up and putting it in the bag.
- Allow the snow in the bags to melt, then completely dry each bag with its collection mat inside.
- When completely dry, weigh the bag with the collection mat inside. Subtract the “unloaded” weight to get the amount of snow-sand load for each 3’ x 10’ collection mat. Record the sand load for each 3’x10’ strip.
- Combine the weights of sand from each “equivalent” 3’ x 10’ collection mat: For example, the northbound 35 mph 20’-30’ strip with the southbound 35 mph 20’-30’ strip), then average the two of them together. (This eliminates the crosswind factor.)
- Tabulate the data.