
Manure Irrigation Workgroup
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Feb 24, 2014
UW Extension
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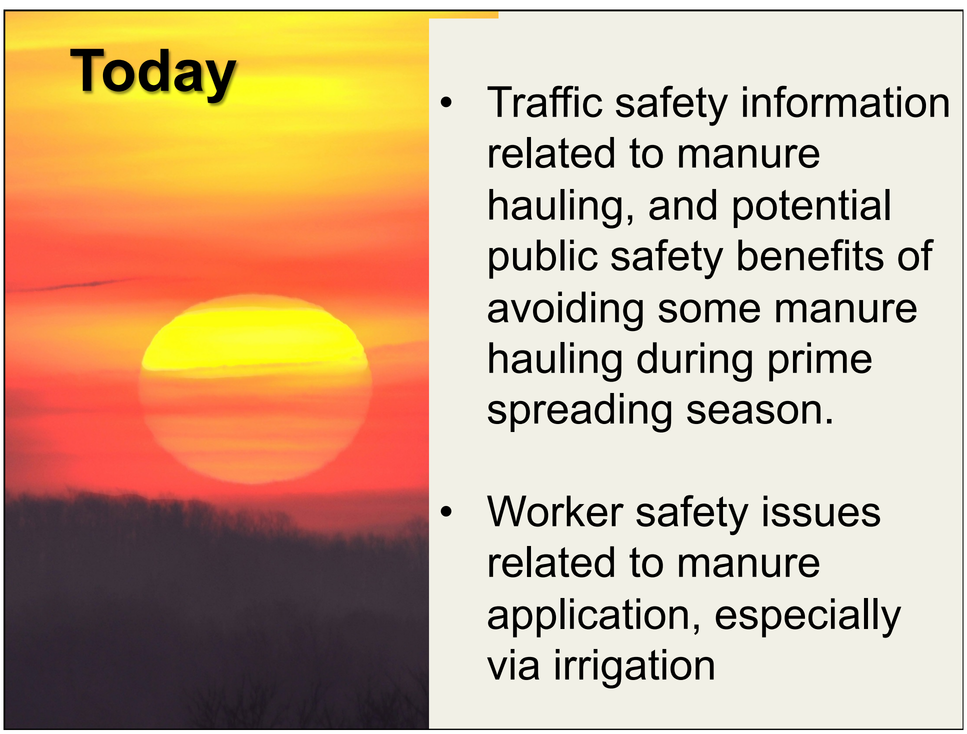
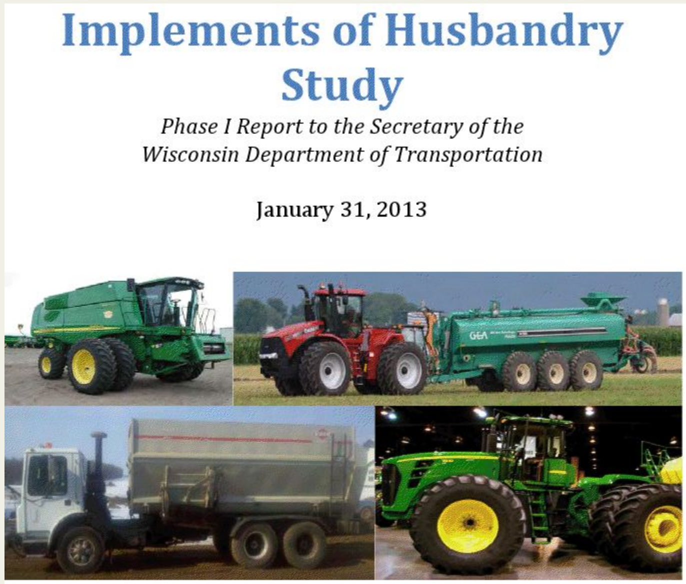
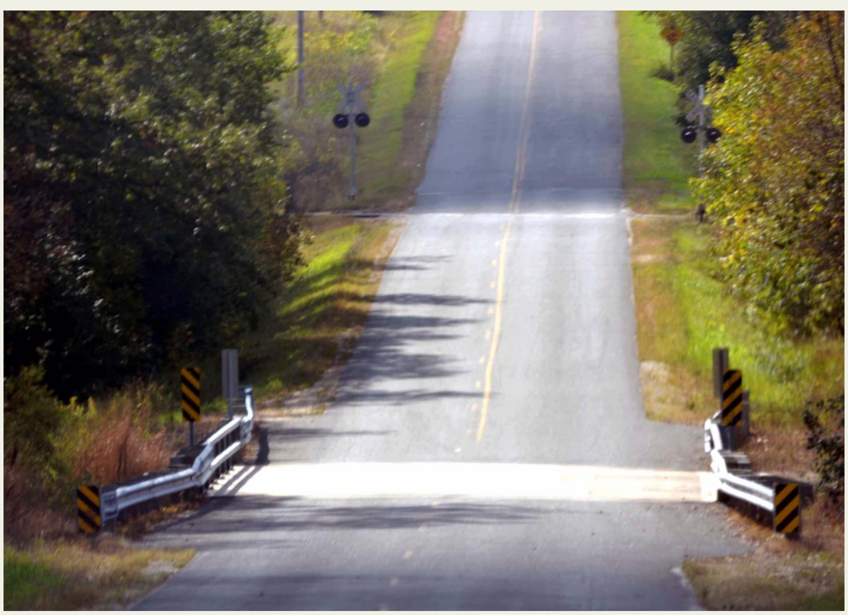
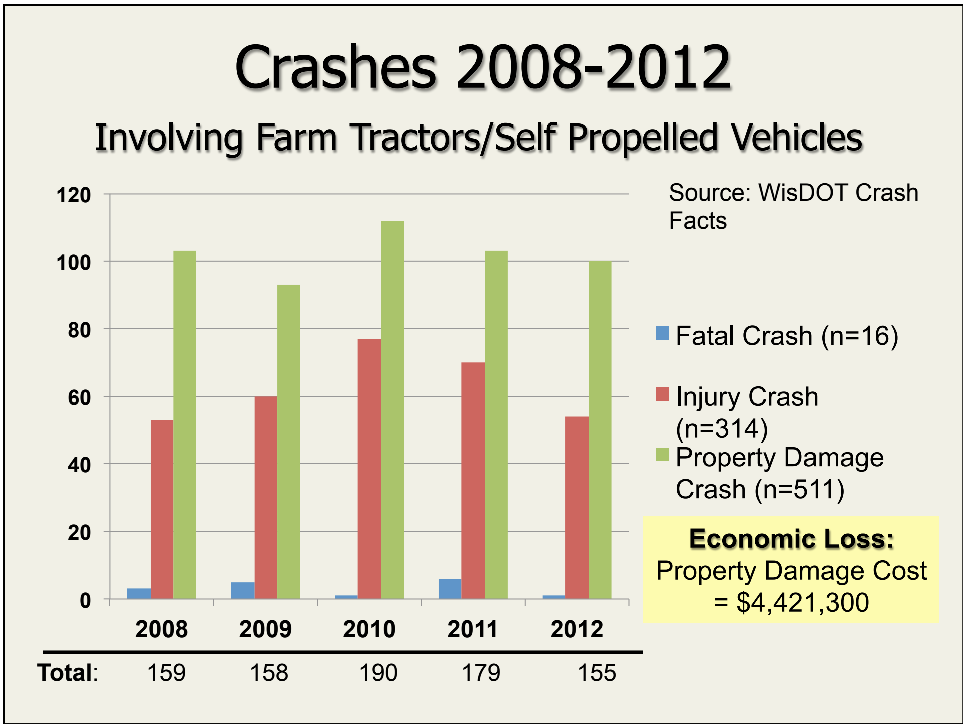

Today
• Traffic safety information related to manure hauling, and potential public safety benefits of avoiding some manure hauling during prime spreading season.
• Worker safety issues related to manure application, especially via irrigation

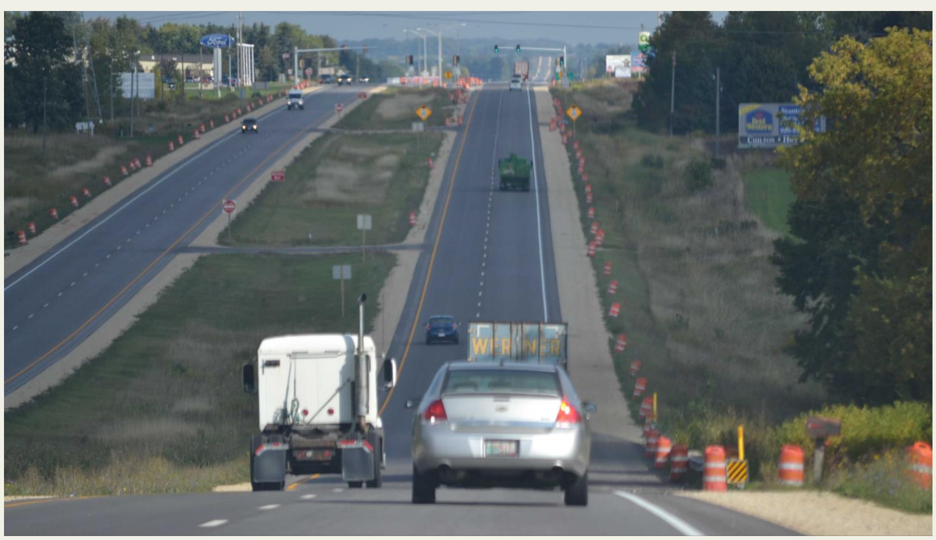


http://www.dot.wisconsin.gov/business/ag/index.htm




Crashes 2008-2012
Involving Farm Tractors/Self Propelled Vehicles
Source: WisDOT Crash Facts
120
100
80
60
40
20
0
2008
2009
2010
2011
2012
Fatal Crash (n=16)
Injury Crash (n=314)
Property Damage Crash (n=511)
Economic Loss:
Property Damage Cost = $4,421,300
Total: 159 158 190 179 155


QT QUAD
NUHN



Worker Safety

- Risk to workers at storage areas
- Risk with irrigation systems
  - Hazard analysis
  - Type of system
  - What's being irrigated

Worker Safety

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  - Hazard analysis
  - Type of system
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MODELING MICROBIAL RISK AND IRRIGATION DRIFT OF WASTEWATERS OF VARYING MICROBIAL QUALITIES FOR DETERMINATION OF BUFFER ZONES

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Introduction

The Idaho Department of Environmental Quality (DEQ) has developed tools and methodologies that model the health risks of wastewater reuse irrigation as well as applying an irrigation drift model to predict volumes of wastewater drifting beyond site boundaries. These efforts are aimed at determining health and nuisance related buffer distances respectively for use by regulatory agencies in permits allowing reuse activities. Part I of this paper describes microbial risk modeling. Part II describes irrigation drift modeling. Model results and applicability to buffer zone determination are also discussed in both parts.

Part I – Microbial Risk Modeling and Buffer Zone Determination

DEQ has developed a 'Tier 1' modeling spreadsheet that models wastewater reuse irrigation and the annual risk of infection by E. coli O157:H7 through airborne and produce ingestion pathways. Risk is expressed here as one infection per number of people exposed. For example, a risk of 10^{-4} would be 1 infection per 10,000 people exposed. Both airborne and ingestion pathways are calculated and plotted separately, and are summed to yield total risk which is also plotted. Model output is risk as a function of distance from the pattern radius (i.e. wetted radius) of the emission source. Emission sources include sprinklers and pivot end guns. Example plots are shown below. Details of model structure, function and assumptions can be found in *Technical Background Document: Microbial Risk Assessment and Fate and Transport Modeling of Aerosolized Microorganisms at Wastewater Land Application Facilities in Idaho, DEQ February 2006*, available for download at:

http://www.deq.idaho.gov/water/data_reports/waste_water/reports.cfm

Scenario Descriptions and Parameter Selection

There are conceivably tens of thousands of scenarios that may be run with the model, but for purposes of this effort, conservative and limited scenarios (~3,300 scenarios) have been selected. Input parameters are described here, including crop and irrigation parameters, meteorological scenarios, and microbial characteristics of Idaho regulated wastewater classes. Figure 1 shows a conceptual model schematic.

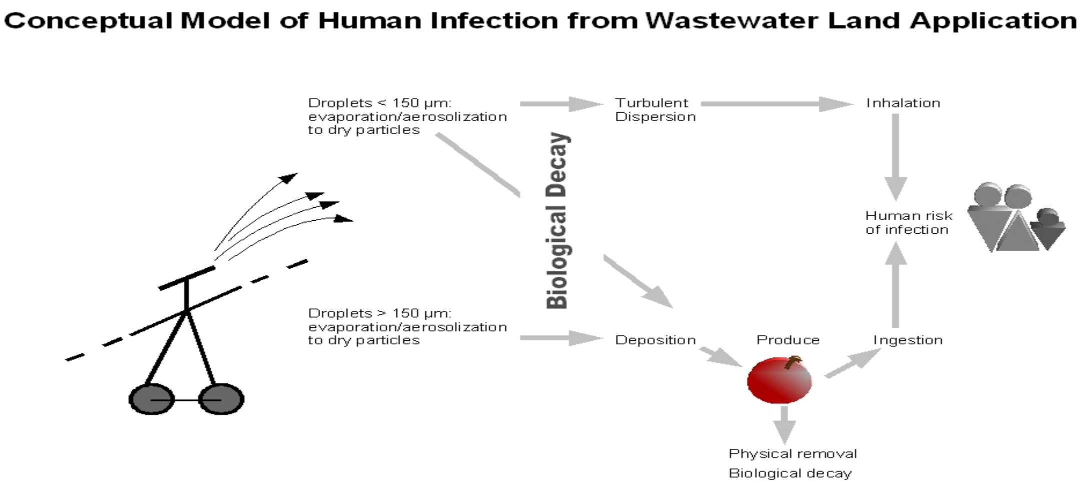

Figure 1. Microbial Risk – Conceptual Model Schematic.

Crop and Irrigation System Parameter Selection

A long irrigation season with a higher water demanding crop has been selected to maximize exposure. The irrigation system assumed is a 126 acre pivot with an approximate 1300 ft radius and discharging 820 gallons per minute (gpm). The crop is alfalfa and the location is near Rupert Idaho. The number of irrigation events is estimated to be 49 throughout an April through early October growing season, and each set is 60 hours and human exposure is assumed to be 8 hours per set. Water irrigated is assumed to be 100 percent wastewater. See Figure 2 showing model geometry.

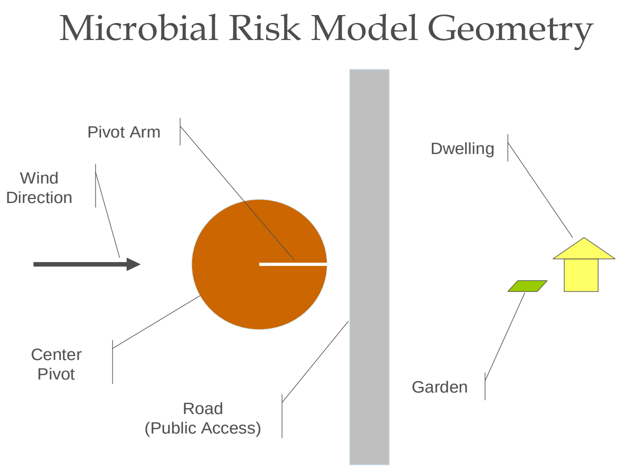

Figure 2. Microbial Risk – Model Geometry.

Four different nozzles are modeled at different operating pressures within their typical range of operation. Pressures have been varied in increments of 10 pounds per square inch (PSI). Further, assumptions of 1% and 10% E. coli as the toxic O157:H7 type were assumed. The 10% estimate is likely very conservative. Nozzle properties as described by Agricultural Research Service (ARS) irrigation drift modeling software are presented in Table 1. See further: *D. Kincaid, November 2002. DRIFT02.wpd. Model Documentation. 4 pages*.

Table 1. Modeled Nozzles and Their Characteristics

Nozzle Type/ Parameter	Wobbler (No. 37)	Impact (No. 7)	Rotator (No. 47)	Rotator (No. 42)	Wobbler (No. 32)	Flatspray (No. 76)
Nozzle ID	SEN-WOBBLA-1/4	RB30-sb 5/32	NS-ROT D6 1/4	NS-ROT D4 1/4	SEN-WOBBLA-1/4	NS-SPFLAT ¼
Operating Pressure (PSI)	10	58	15	15	20	20
Sprinkler Spacing (ft)	9	9	9	9	9	9
Sprinkler Height (ft)	6	15	6	6	6	6.5
Discharge Rate (gpm)	5.8	5.0	6.8	6.8	8.0	7.8
Linear Discharge Rate (gpm)[1]	$\frac{5.8\ gpm}{9\ ft}*5=3.22$	$\frac{5.0\ gpm}{9\ ft}*5=2.78$	$\frac{6.8\ gpm}{9\ ft}*5=3.78$	$\frac{6.8\ gpm}{9\ ft}*5=3.78$	$\frac{8.0\ gpm}{9\ ft}*5=4.44$	$\frac{7.8\ gpm}{9\ ft}*5=4.33$
Nozzle Trajectory (degrees)	23	23	10	10	23	0
Wetting Radius (ft)	30	48	28	33	36	23

1) The linear discharge rate is the discharge rate divided by sprinkler spacing, then multiplied by a factor depending on the orientation of the pivot lateral with respect to wind direction. For an orientation of 0 degrees from downwind (i.e. the pivot arm downwind of the pivot center and parallel to wind direction) the factor is '5'. See Kincaid 2002, p. 3.

Meteorological Scenario Descriptions

In addition to these parameters, four meteorological scenarios have been modeled; F-1 stability at 1 meter per second (mps) which represents calm night conditions with clear skies; D-10 stability at 10 mps which represents windy daytime conditions; and D-2.5 stability conditions at 2.5 mps which represents typical daytime conditions.

Wastewater Class Scenario Descriptions

All classes of municipal wastewater regulated in Idaho have been modeled and are described in Table 2.

Table 2. Idaho Wastewater Classes

Wastewater Class/ Parameter	Class A	Class B	Class C	Class D	Class E
Total Coliform Count CFU/100 mL	2.2	2.2	23	230	Too numerous to Count

Since there are no numerical standards for Class E wastewater, and since the model needs quantitative inputs, 2,300,000 CFU/100mL was chosen to represent the designation 'too numerous to count' (TNTC).

Each wastewater class at each of three distances from the source was modeled for 46 scenarios, varying nozzle types, operating pressures and wastewater pathogen content. Each of the 46 scenarios was modeled for 1) both airborne and total risk, 2) three meteorological conditions. Results were compiled at three distances; 50 feet, 300 feet and 1320 feet from the pattern radius. All sub-scenarios number ~3,300. Examples modeled output for 50 feet are shown in Tables 4, 5, 6 and 7. It should be possible in many cases to find one of these scenarios that adequately or conservatively represent a site-specific situation for which a buffer distance needs to be determined.

For all scenarios, risk as a function of distance from the emission source was recorded as either '*de minimis*' ($<10^{-8}$ risk), 'low' (between 10^{-8} and 10^{-6} risk), 'concern' (between 10^{-6} and 10^{-4}), 'threshold' (over the proposed risk threshold of 10^{-4} but less than 10^{-2}), and 'high' (above 10^{-2}). As will be discussed below, there are many acceptable scenarios within each wastewater type, nozzle type, and operating pressures. Class E wastewaters are far more limiting with respect to buffer zone distances due to the very high total coliform input parameter chosen.

Model Output

Examples modeled output for 50 feet are shown in Tables 4, 5, 6, and 7. In these tables the various input parameters and descriptions are in the column headers. The body of the tables shows the scenario number to the left, then wastewater class, total coliform count, percent O157:H7 of total coliform, nozzle type, and operating pressure. To the right on the tables appear the meteorological scenarios described above. In the cells are ratings from 1 to 5 in conditionally formatted cells corresponding to '*de minimis*' (1, no color), 'low' (2, yellow), 'concern' (3, light orange), 'threshold' (4, orange), and 'high' (red). Section 3.3 describes numerical risk values associated with these rankings.

Model Output

There are several observations that can be made for Class A/B, C, D and E outputs. Table 3 shows generalized risk categories (previously defined above) for different wastewater classes and distances. Risk categories are listed in the cells of Table 3 by rank in order of most to least frequent occurring risk rating.

The following are general observations of the risk results.
1) Class A/B wastewaters show *de minimis* or low risk for all scenarios.
2) Class C wastewaters show risk lower than 'threshold' for all scenarios.
3) Class D wastewaters show airborne and total risk below 'threshold' for all scenarios with the exception of total risk at 50 feet, which shows some scenarios above 'threshold' risk.
4) Class E wastewaters show high total risk for most scenarios, especially at 50 feet and 300 feet. Most scenarios for airborne risk show at least 'threshold' levels both at 50 feet and 300 feet. At 1320 feet, airborne risk is less than 'threshold' level.

Table 3. Risk Categories for Wastewater Classes and Distance

WW Class	50 feet		300 feet		1320 feet	
	Airborne Risk	Total Risk	Airborne Risk	Total Risk	Airborne Risk	Total Risk
Class A/B	'*de minimis*' and 'low'	'*de minimis*' and 'low'	*de minimis*	*de minimis*	*de minimis*	*de minimis*
Class C	'low', '*de minimis*', and 'concern'	'low', 'concern' and '*de minimis*'	'*de minimis*' and 'low'	'*de minimis*' and 'low'	*de minimis*	*de minimis*
Class D	'low', 'concern', and '*de minimis*',	'concern', 'low', and 'threshold'	'low', and '*de minimis*',	'low', 'concern' and '*de minimis*',	*de minimis*	'*de minimis*' and 'low'
Class E	'threshold', 'high' and 'concern'	'high' and 'threshold',	'threshold', and 'concern'	'high' 'threshold', and 'concern'	'low', 'concern', and '*de minimis*'	'low', 'concern', 'high', 'threshold', and '*de minimis*'

Graphical Model Output

Graphical output is shown in Figures 3, 4, and 5. Risk values are on the ordinate and distance from the source is on the abscissa. The zero on the x-axis represents the edge of the pattern radius of the sprinkler, and not the sprinkler location itself. Pattern radii differ with different sprinklers. The first calculation (and data point plotted) appears on the plots at 10 m (32.8 feet) from the sprinkler pattern radius. Thus there is no estimation of risk between zero feet and 32.8 feet. Total risk and airborne risk are represented by the solid line and dotted lines respectively. The red horizontal line represents the threshold risk level as determined in this document (10^{-4}). The three vertical lines from left to right mark the distances 50 feet, 300 feet, and 1320 feet respectively. And finally, the various risk rankings are labeled with text boxes and parentheses.

The example selected in the following figures is a Class D wastewater, 10% of total coliform as O157:H7, the pivot utilizing impact sprinklers operating at 60 psi.

In Figure 3, calm nighttime conditions (F-1 Stability), total risk is below threshold at slightly farther than 50 feet from the pattern radius of the sprinkler. Airborne risk is below threshold for all plotted values.

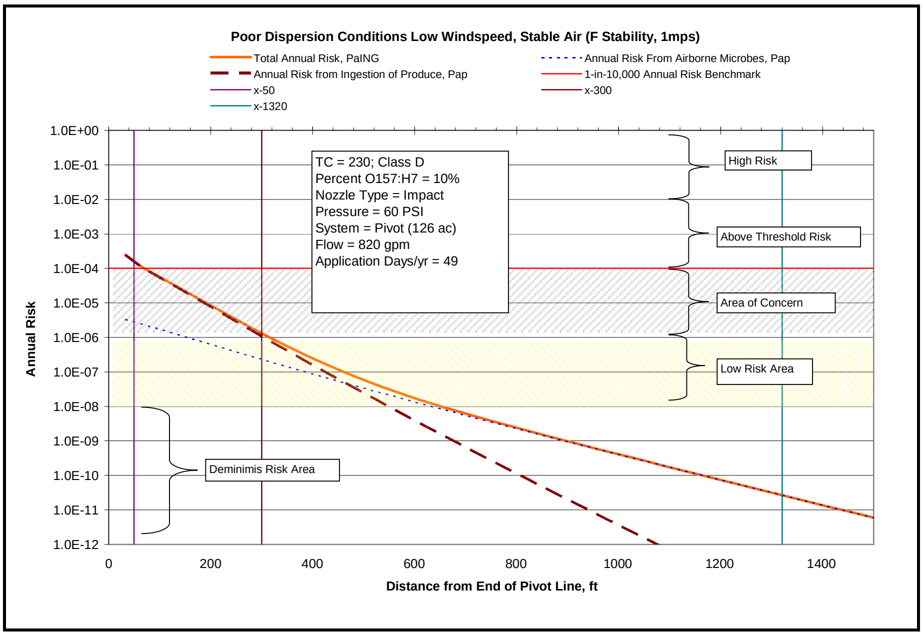

Figure 3. Risk at F-1 Stability.

In daytime breezy conditions (D-10 stability) in Figure 4, total risk is predicted to be below threshold at a distance of ~130 feet from the pattern radius, most likely due to winds carrying ad depositing pathogens farther from the source. Airborne risk is predicted to be below threshold at any distance, and is lower than for F-1 conditions due to the increased dilution of pathogen-containing air from increased wind.

Figure 5 shows risk in gentle daytime breeze. Both airborne and total risk are well below threshold, airborne risk being intermediate between F-1 and D-10 conditions, and total risk being lower that both F-1 and D-10 conditions.

Using these example results in setting a buffer zone for public access, it would be prudent to set it at ~55 feet or slightly greater in light of D-10 conditions. In setting a buffer zone for dwellings, ~130 or slightly greater could be considered, also in light of D-10 conditions. If meteorological instrumentation is considered for monitoring weather conditions, buffer zones could also be set contingent upon allowing land application under certain conditions, such as wind speeds not exceeding 5 mph (2.5 mps). In such cases, lower buffer zones could be considered.

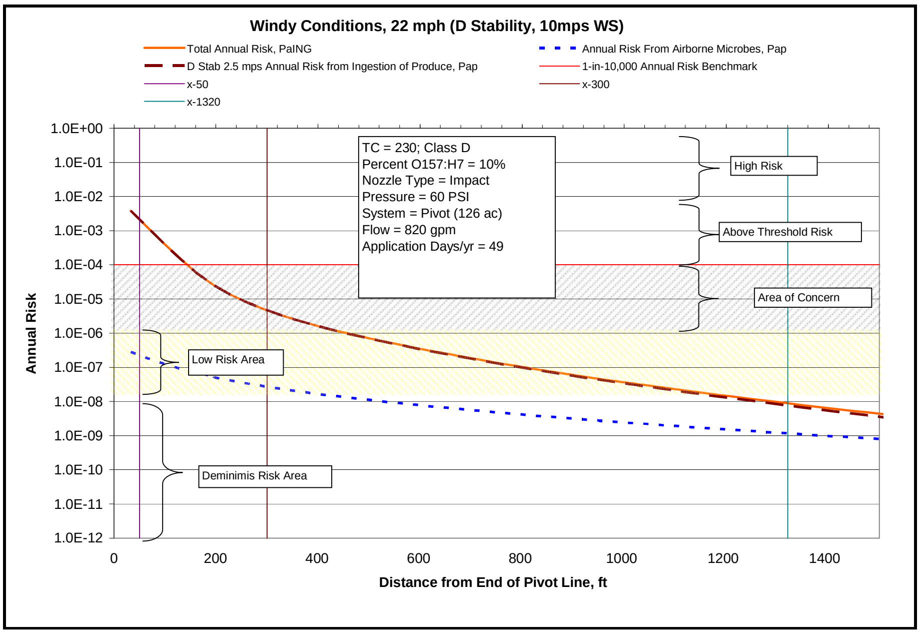

Figure 4. Risk at D-10 Stability.

It is important to mention that buffer zones discussed here are only in reference to health risk, not nuisance concerns. The latter is a separate analysis with different criteria and is discussed in Part II below.

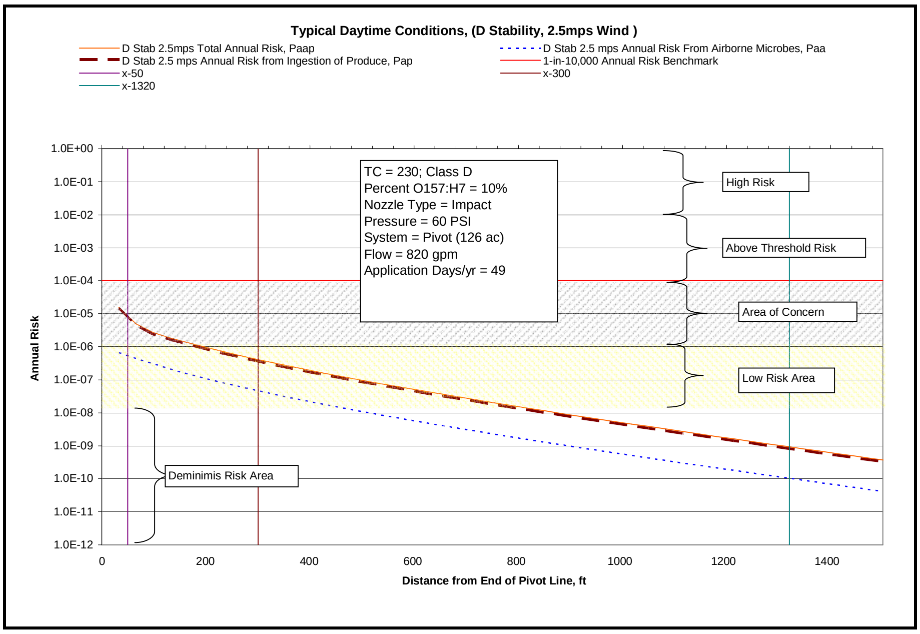

Figure 5. Risk at D-2.5 Stability.

Risk Assessment Threshold Determination

Assigning a threshold value for acceptable risk requires careful consideration of acceptable risk determinations in several regulatory and environmental contexts, and determination of their degree of applicability to wastewater reuse/land treatment. For purposes of this analysis, a threshold risk of infection value of one in ten thousand (10^{-4}) is proposed. When addressing lifetime cancer risk, regulatory programs have typically considered risks to be acceptable or *de minimis* when the incremental lifetime increase in risk of cancer as a result of exposure to environmental contaminants is one in one million (10^{-6}).

Depending on the federal or state regulatory program, levels of acceptable risk are often explicitly or implicitly derived from the 10^{-6} to 10^{-4} risk range identified in the National Contingency Plan, and used by the EPA Superfund Program. The lower probability, 10^{-6} is considered a point of departure; risks below this level are *de minimis*. However, risks up to 10^{-4} are often considered acceptable, and a risk of 10^{-4} is a common reference level in remedial decision-making.

Intermittent exposure to microbial pathogens related to wastewater reuse is different from chronic exposure to chemical contaminants, and the concern is infection rather than chemically induced cancer or some other health effect. However, it is still possible, when considering the probability of infection, to determine that some low level of probability is acceptable.

Considering the nature of the exposure, risks considered to be acceptable can be based on various timeframes. The probability of infection can be evaluated for the duration of an individual exposure event, a year, or a lifetime. EPA made the determination in the Giardia rule that an annual probability of infection of 10^{-4} is acceptable. So this level of risk appears to be appropriate for consideration as an acceptable level of risk from potential exposure during water reuse/land treatment occurring intermittently though the year, or some season of the year.

Risk Assessment Modeling: Compilations of Output

This section contains example compiled model output for Class A/B and Class D wastewaters only, at a distance of 50 feet. For outputs of other wastewater classes and distances, see Cook and Fromm (2010). The key to the color coding is discussed in the section 'Model Outputs' above. Notice that there is deminimus or low risk for all wastewater class A/B scenarios. For the Class D scenarios, several exceed the 'threshold' risk, but many more are below this threshold. This indicates that there are many options for a facility to design and operate an irrigation system that would accommodate risk criteria.

Table 4. Class A/B Wastewater Scenarios and Risk

						Meteorological Stability Classes)					
Scenario	WW Class	Total Coliform	Pct O157	Nozzle	Pressure	F-1; Air	F-1; Total	D-10; Air	D-10; Total	D-2.5; Air	D-2.5; Total
1	Class A/B	2.2	1%	Rotator	10	1	1	1	1	1	1
2	Class A/B	2.2	1%	Rotator	20	1	1	1	1	1	1
3	Class A/B	2.2	1%	Rotator	30	1	1	1	1	1	1
4	Class A/B	2.2	10%	Rotator	10	1	1	1	2	1	2
5	Class A/B	2.2	10%	Rotator	20	2	2	1	2	1	2
6	Class A/B	2.2	10%	Rotator	30	2	2	1	2	1	2
7	Class A/B	2.2	1%	Flat Spray	10	1	1	1	1	1	1
8	Class A/B	2.2	1%	Flat Spray	20	1	1	1	1	1	1
9	Class A/B	2.2	1%	Flat Spray	30	1	1	1	1	1	1
10	Class A/B	2.2	10%	Flat Spray	10	2	2	1	2	1	2
11	Class A/B	2.2	10%	Flat Spray	20	2	2	1	2	1	2
12	Class A/B	2.2	10%	Flat Spray	30	2	2	1	2	1	2
13	Class A/B	2.2	1%	Wobbler	10	1	1	1	1	1	1
14	Class A/B	2.2	1%	Wobbler	20	1	1	1	1	1	1
15	Class A/B	2.2	1%	Wobbler	30	1	1	1	1	1	1
16	Class A/B	2.2	1%	Wobbler	40	1	1	1	1	1	1
17	Class A/B	2.2	10%	Wobbler	10	1	1	1	1	1	2
18	Class A/B	2.2	10%	Wobbler	20	1	1	1	2	1	2
19	Class A/B	2.2	10%	Wobbler	30	2	2	1	2	1	2
20	Class A/B	2.2	10%	Wobbler	40	2	2	1	2	1	2
21	Class A/B	2.2	1%	Impact	20	1	1	1	1	1	1
22	Class A/B	2.2	1%	Impact	30	1	1	1	1	1	1
23	Class A/B	2.2	1%	Impact	40	1	1	1	1	1	1
24	Class A/B	2.2	1%	Impact	50	1	1	1	1	1	1
25	Class A/B	2.2	1%	Impact	60	1	1	1	1	1	1
26	Class A/B	2.2	1%	Impact	70	1	1	1	1	1	2
27	Class A/B	2.2	1%	Impact	80	1	1	1	1	1	2
28	Class A/B	2.2	10%	Impact	20	1	1	1	2	1	2
29	Class A/B	2.2	10%	Impact	30	2	2	1	2	1	2
30	Class A/B	2.2	10%	Impact	40	2	2	1	2	1	2
31	Class A/B	2.2	10%	Impact	50	2	2	1	2	1	2
32	Class A/B	2.2	10%	Impact	60	2	2	1	2	1	2
33	Class A/B	2.2	10%	Impact	70	2	2	1	2	1	2
34	Class A/B	2.2	10%	Impact	80	2	2	1	2	1	2
35	Class A/B	2.2	1%	Endgun no.15	Impact no. 7	1	1	1	1	1	1
36	Class A/B	2.2	1%	Endgun no.15	Rotator no. 42	1	1	1	1	1	1
37	Class A/B	2.2	1%	Endgun no.15	Wobbler no. 37	1	1	1	1	1	1
38	Class A/B	2.2	1%	Endgun no.17	Impact no. 7	1	1	1	1	1	1
39	Class A/B	2.2	1%	Endgun no.17	Rotator no. 42	1	1	1	1	1	1
40	Class A/B	2.2	1%	Endgun no.17	Wobbler no. 37	1	1	1	1	1	1
41	Class A/B	2.2	10%	Endgun no.15	Impact no. 7	2	2	1	2	1	2
42	Class A/B	2.2	10%	Endgun no.15	Rotator no. 42	1	2	1	1	1	2
43	Class A/B	2.2	10%	Endgun no.15	Wobbler no. 37	1	1	1	1	1	2
44	Class A/B	2.2	10%	Endgun no.17	Impact no. 7	2	2	1	2	1	2
45	Class A/B	2.2	10%	Endgun no.17	Rotator no. 42	2	2	1	2	1	2
46	Class A/B	2.2	10%	Endgun no.17	Wobbler no. 37	1	1	1	1	1	2

Table 5. Class D Wastewater Scenarios and Risk

	WW Class	Total Coliform	Pct O157	Nozzle	Pressure	F-1; Air	F-1; Total	D-10; Air	D-10; Total	D-2.5; Air	D-2.5; Total
93	Class D	230	1%	Rotator	10	2	2	1	3	2	2
94	Class D	230	1%	Rotator	20	2	2	2	3	2	2
95	Class D	230	1%	Rotator	30	2	2	2	3	2	2
96	Class D	230	10%	Rotator	10	2	3	2	4	2	3
97	Class D	230	10%	Rotator	20	3	3	2	4	2	3
98	Class D	230	10%	Rotator	30	3	3	2	4	2	3
99	Class D	230	1%	Flat Spray	10	2	2	1	3	2	2
100	Class D	230	1%	Flat Spray	20	2	2	2	3	2	2
101	Class D	230	1%	Flat Spray	30	2	3	2	3	2	2
102	Class D	230	10%	Flat Spray	10	2	3	2	4	2	3
103	Class D	230	10%	Flat Spray	20	3	3	2	4	2	3
104	Class D	230	10%	Flat Spray	30	3	3	2	4	2	3
105	Class D	230	1%	Wobbler	10	2	2	1	2	1	2
106	Class D	230	1%	Wobbler	20	2	2	1	3	2	2
107	Class D	230	1%	Wobbler	30	2	2	1	3	2	2
108	Class D	230	1%	Wobbler	40	2	2	2	3	2	2
109	Class D	230	10%	Wobbler	10	2	3	2	3	2	3
110	Class D	230	10%	Wobbler	20	2	3	2	4	2	3
111	Class D	230	10%	Wobbler	30	2	3	2	4	2	3
112	Class D	230	10%	Wobbler	40	3	3	2	4	2	3
113	Class D	230	1%	Impact	20	2	2	1	3	2	2
114	Class D	230	1%	Impact	30	2	2	1	3	2	2
115	Class D	230	1%	Impact	40	2	2	2	3	2	2
116	Class D	230	1%	Impact	50	2	3	2	3	2	2
117	Class D	230	1%	Impact	60	2	3	2	3	2	2
118	Class D	230	1%	Impact	70	2	3	2	3	2	3
119	Class D	230	1%	Impact	80	2	3	2	3	2	3
120	Class D	230	10%	Impact	20	2	3	2	4	2	3
121	Class D	230	10%	Impact	30	3	3	2	4	2	3
122	Class D	230	10%	Impact	40	3	3	2	4	2	3
123	Class D	230	10%	Impact	50	3	4	2	4	2	3
124	Class D	230	10%	Impact	60	3	4	2	4	2	3
125	Class D	230	10%	Impact	70	3	4	2	4	2	3
126	Class D	230	10%	Impact	80	3	4	2	4	2	3
127	Class D	230	1%	Endgun no.15	Impact no. 7	2	2	2	3	2	2
128	Class D	230	1%	Endgun no.15	Rotator no. 42	2	2	1	2	2	2
129	Class D	230	1%	Endgun no.15	Wobbler no. 37	2	2	1	2	1	2
130	Class D	230	1%	Endgun no.17	Impact no. 7	2	3	2	3	2	2
131	Class D	230	1%	Endgun no.17	Rotator no. 42	2	2	1	3	2	2
132	Class D	230	1%	Endgun no.17	Wobbler no. 37	2	2	1	2	1	2
133	Class D	230	10%	Endgun no.15	Impact no. 7	3	3	2	4	2	3
134	Class D	230	10%	Endgun no.15	Rotator no. 42	2	3	2	3	2	3
135	Class D	230	10%	Endgun no.15	Wobbler no. 37	2	3	2	3	2	3
136	Class D	230	10%	Endgun no.17	Impact no. 7	3	3	2	4	2	3
137	Class D	230	10%	Endgun no.17	Rotator no. 42	3	3	2	4	2	3
138	Class D	230	10%	Endgun no.17	Wobbler no. 37	2	3	2	3	2	3

Part II – Irrigation Drift Modeling for Determination of Buffer Distances

The characterization effort described here models the volume of deposition of land applied wastewater irrigation drift (>0.1 mm sized droplets) as a function of the distance from the source, and how the quantifying of this deposition may help characterize nuisance conditions as well as setting quantitative buffer zone criteria for regulatory purposes.

Not included in this characterization are aerosolized particles (<0.1 mm sized droplets). These do not have a ballistic trajectory as do drift-sized particles, and achieve buoyancy and can travel over long distances. Aerosolized particles from wastewater are mostly evaporated and the particle itself consists only of the solids in the wastewater, so the aerosolized particle would no longer be considered 'wastewater'.

Modeling

The modeling tool used was the Irrigation Drift Model (2002), developed by Dr. Dennis Kincaid, Agricultural Research Service (ARS), Northwest Irrigation and Soils Research Laboratory in Kimberly Idaho. This tool models the ballistic trajectories of forty (40) droplet sizes (0.1 mm – 7.8 mm), their relative volumes, distance traveled, evaporation losses, temperature changes, and droplet impact energies (Kincaid, 2002). Figure 6 shows a conceptual model schematic.

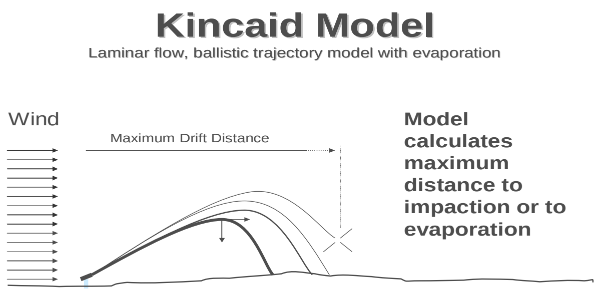

Figure 6. Kincaid Model – Conceptual Schematic.

The model generates volumes and respective distances traveled for forty different droplet sizes. Thus there are forty data points generated for each wind speed scenario. The sum of the volumes of these forty values equals the total discharge of the sprinkler during the irrigation set. A deposition rate can be calculated as a function of distance from the emission source. The tool is capable of modeling 78 different types of sprinkler nozzles.

Scenario Descriptions

Scenario Descriptions

For purposes of this effort, conservative and representative pivot irrigation scenarios for Idaho conditions have been selected. Input parameters are described here.

The irrigation system assumed is a 126 acre pivot with an approximate 1300 ft radius and discharging 820 gallons per minute (gpm). The crop is alfalfa and the location is near Kimberly Idaho. A long irrigation season with a higher water demanding crop has been selected to maximize irrigation events and deposition. Irrigation events take place throughout an April through early October growing season.

Each set is 60 hours, which means a 15 hour residence time for each 90 degree pivot quadrant. Assuming that the significant drift would occur over a pivot travel time equivalent to half of the quadrant, this would be a ~22 degree arc taking about 8 hours and be in closest downwind proximity to a downwind receptor. It is then assumed that receptor exposure is 8 hours per set. See Figure 7 for a schematic of the scenario modeled.

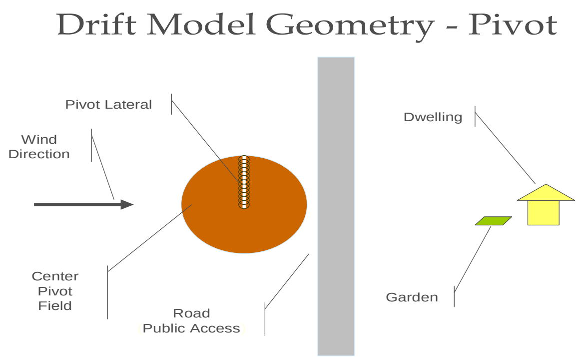

Figure 7. Drift Model Scenario Schematic.

Irrigation conditions assumed are as follows: Irrigation water temperature is 60° F and ambient air temperature is 67° F. Relative humidity is assumed to be 95% for purposes of modeling a worse case scenario where there is minimal droplet evaporation and maximum travel distances. The Kimberly area elevation is 3921 feet. Wind speeds modeled are 0 miles per hour (mph), 5 mph, 10 mph, and 20 mph [0 meters per second (mps), 2.2 mps, 4.5 mps, and 22 mps respectively].

Sprinkler Nozzle Parameter Selection

Five different nozzles are modeled which represent sprinklers that are typically used in south-central Idaho for an alfalfa crop (Neibling, 2009). The nozzles represent typical Wobbler, impact, Rotator, and flatspray configurations and are described in Table 1. Three horizontal nozzle trajectory angles are modeled (not to be confused with the nozzle trajectory angle in the vertical direction). These three angles are 0 degrees (when the nozzle is pointed downwind) 90 degrees (when perpendicular to the wind direction), and 180 degrees (when pointed upwind). Note that the impact sprinkler configuration is utilized mainly for irrigating wastewater from dairy waste lagoons in south-central Idaho.

Drift Model Output

Model output from two of the six sprinkler types (low pressure Wobbler and impact sprinklers) at four wind speeds can be seen in Figures 8 and 9. These show the volume of irrigation drift passing beyond certain distances for four wind speeds for each sprinklers for an 8 hour period. Deposition beyond the wetting radius of the sprinkler (i.e. beyond the area designed to be wetted for irrigation) is the area of concern. Buffer distances would be set starting at the boundary of wetted radii outward.

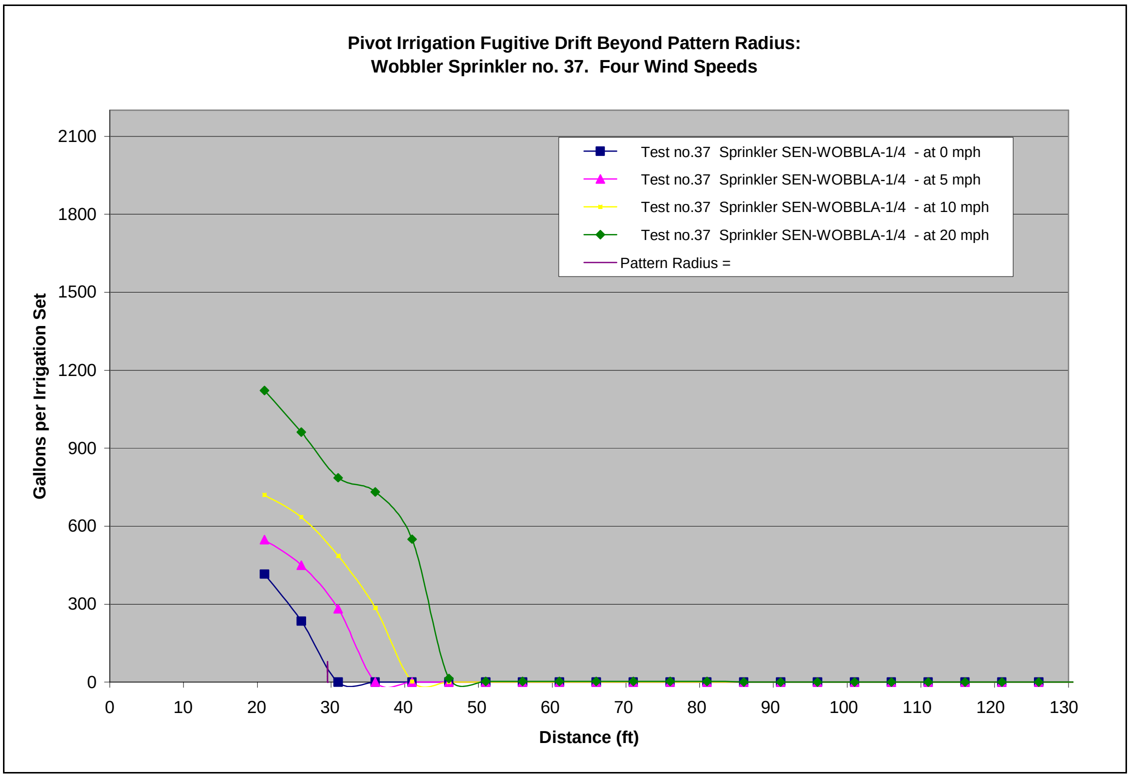

Figure 8. Fugitive Irrigation Drift Beyond Pattern Radius – Wobbler Sprinkler.

As can be seen by Figures 8 and 9, there are significant differences in the volume of drift at distance between the different sprinklers modeled. The low pressure Wobbler (as well as the Rotator and flatspray not shown) generate significantly less drift than the impact sprinkler (and higher-pressure Wobbler not shown). Modeling drift can be utilized to determine nuisance buffer zones by assigning a volumetric threshold of drift over time that would represent a level of aesthetic nuisance acceptable for a particular wastewater. Such a threshold level could then be used in the design or retrofit of wastewater irrigation systems so that the systems do not generate an unacceptable volume of drift at a specified distance.

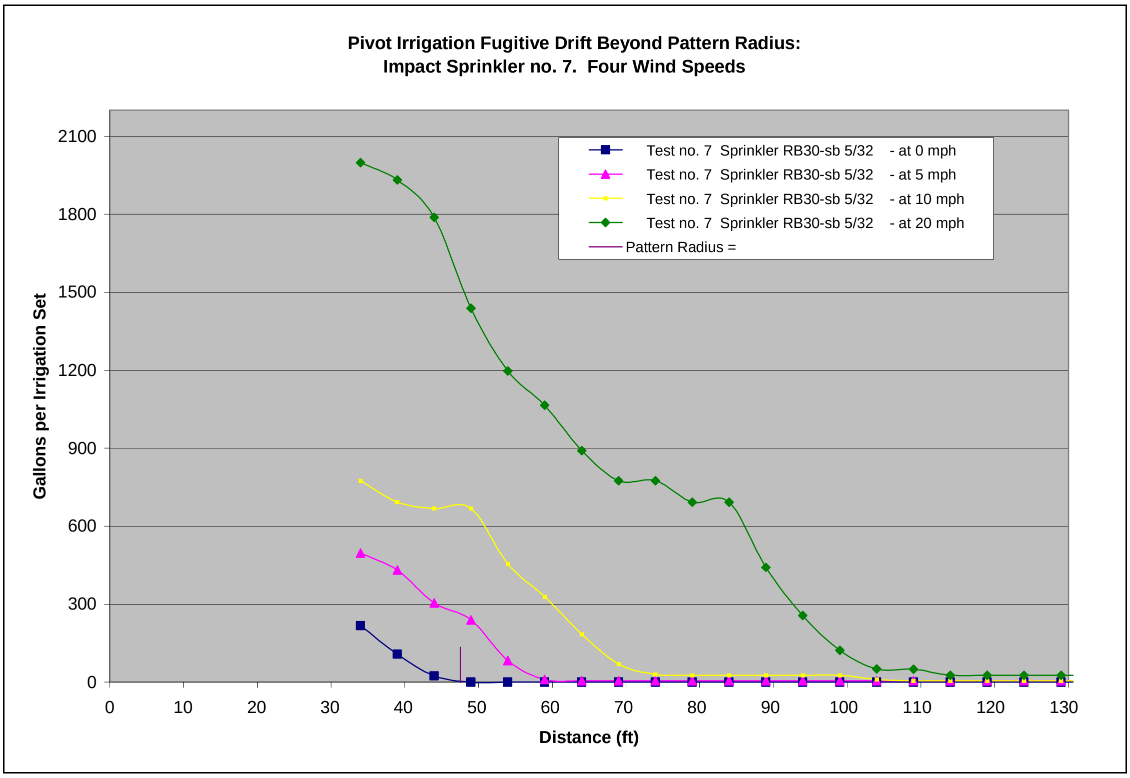

Figure 9. Fugitive Irrigation Drift Beyond Pattern Radius – Impact Sprinkler.

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