Alternatives of MACCS2 in LANL Dispersion Analysis for Onsite and Offsite Doses

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John H. C. Wang, Ph.D.

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Los Alamos National Laboratory

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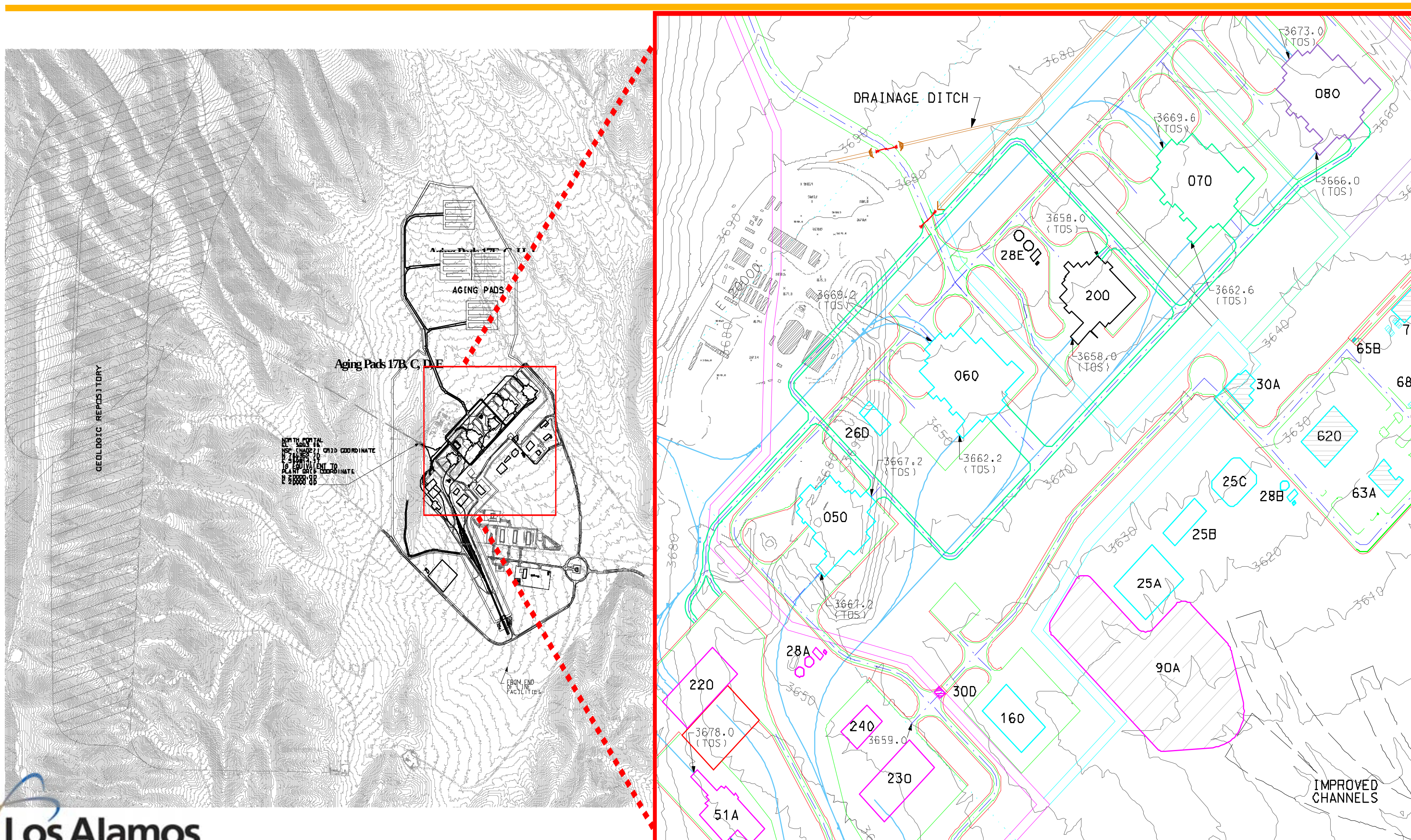
Deficiency of MACCS2 for Onsite Worker Application in YMP

- MACCS2 is not well suited for modeling dispersion close to the source (e.g., less than 100 meters and building wakes)
- Inflexibility of yearly data requirement on meteorological inputs (requires only single year of meteorological data with complete hourly records).
- Inflexibility to diverse configurations of release and receptor.

ARCON96 for YMP Preclosure Safety Analysis

- A Gaussian dispersion code with building wake/cavity algorithms validated by wind tunnel studies and lateral plume meander validated by field tracer measurements.
- It is the result of many years of NRC sponsored studies conducted by PNNL evaluating the Murphy-Campe models using experimental data and developing alternative approaches.
- In many cases, especially for sites with a high frequency of very stable light wind speed conditions, ARCON96 has provided a marked reduction in χ/Q values compared to the traditional Murphy-Campe models.

General layout of YMP



Release and Receptors for ARCON96 Modeling

- Releases:
  - Different release points of facilities
  - Various facilities or operation areas: Initial Handling Facility, Low Level Waste Handling Facility, Wet Handling Facility, Receipt Facility, Canister Receipt and Closure Facility 1/2/3, Aging Facility 17K/L/M/N, Subsurface Exhaust Shaft 1/2/3S/3N/4/ECRB
- Receptors:
  - Intakes or receptor locations of facilities
  - Various facilities or operation areas: Wet Handling Facility, Receipt Facility, Canister Receipt and Closure Facility 1/2/3, Aging Facility 17K/L/M/N, Administration Complex, Heavy Equipment Maintenance Facility, Central Communication Control Facility, Warehouse and Non-Nuclear Receipt Facility, Utility Facility, Craft Shop, Security Station A/B/C, Subsurface Intake 1/2/3/4/ECRB

Dispersion Modeled by ACRON96 in YMP

- 5 consecutive years of YMP site-specific meteorological data
- ground-level and elevated releases
- with and without significant building wake effects
- various exit velocities and flow rates
- ground-level and elevated intakes
- point and areal sources
- variations of downwind distance (from 11.3 m to 6 km)

Onsite Annual Average χ/Q's of YMP

Receptor Location	Annual Average Atmospheric Dispersion Factor (s/m³) for Release from Facility											
	50	160	17RE	17RW	17PN	17PS	ES1	ES2	ES3N	ES3S	ES4	ECRB
60	2.2E-05	1.5E-05	3.5E-06	4.1E-06	2.3E-06	2.5E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
70	6.5E-06	5.5E-06	6.0E-06	5.5E-06	2.9E-06	3.3E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
80	4.4E-06	4.1E-06	6.8E-06	5.3E-06	3.2E-06	3.6E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
200	1.5E-05	9.3E-06	4.6E-06	4.6E-06	2.5E-06	2.9E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
50	1.8E-03	4.9E-05	1.6E-06	2.8E-06	1.6E-06	1.6E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
51A	9.8E-06	3.5E-06	1.1E-06	1.7E-06	1.2E-06	1.1E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
160	2.4E-05	5.5E-05	1.4E-06	3.1E-06	1.6E-06	1.5E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
17RE	6.7E-06	4.8E-06	NA	7.9E-06	7.2E-06	1.0E-05	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
17RW	6.9E-06	5.5E-06	2.7E-06	NA	3.9E-06	3.5E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
17PN	4.5E-06	1.7E-06	2.2E-06	2.4E-06	NA	1.1E-05	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
17PS	5.3E-06	2.1E-06	3.8E-06	3.5E-06	3.2E-05	NA	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
IS2	2.4E-08	1.0E-08	1.4E-07	1.5E-07	1.5E-07	1.4E-07	4.6E-06	4.2E-07	8.7E-07	1.0E-06	2.3E-06	1.1E-06
IS3	3.3E-08	3.0E-08	1.6E-07	1.8E-07	1.7E-07	1.6E-07	5.1E-07	2.0E-07	1.3E-05	9.1E-07	5.9E-07	3.3E-07
IS4	1.1E-08	9.5E-09	1.1E-07	1.2E-07	1.2E-07	1.2E-07	4.3E-06	2.7E-07	4.3E-07	3.3E-07	1.5E-05	8.3E-07
NC	1.5E-06	6.3E-07	4.3E-07	6.1E-07	4.4E-07	4.1E-07	3.3E-07	2.1E-07	2.2E-06	6.5E-07	4.3E-07	2.6E-07
NP	1.0E-05	2.4E-06	8.7E-07	1.41-06	9.9E-07	9.1E-07	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
SP	6.9E-06	9.0E-07	3.8E-07	4.7E-07	4.2E-07	4.1E-07	1.1E-06	9.4E-07	8.0E-07	1.1E-06	9.6E-07	1.2E-06
220	1.3E-05	4.2E-06	9.8E-07	1.7E-06	1.1E-06	1.1E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
240	6.7E-06	2.9E-06	1.6E-06	2.4E-06	1.5E-06	1.5E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
230	5.2E-06	2.3E-06	1.8E-06	2.3E-06	1.5E-06	1.6E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
25A	1.1E-06	9.2E-07	3.1E-06	3.0E-06	2.0E-06	2.2E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
620	1.3E-06	8.5E-07	3.5E-06	3.3E-06	2.2E-06	2.5E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
71A	1.5E-06	7.8E-07	4.1E-06	3.5E-06	2.5E-06	2.8E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
30A	1.2E-06	1.2E-06	3.2E-06	3.2E-06	2.1E-06	2.3E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
30B	5.4E-06	2.3E-06	1.5E-06	1.5E-06	1.2E-06	1.3E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
30C	3.9E-06	2.8E-06	9.6E-06	6.2E-06	3.8E-06	4.6E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
27A	1.6E-05	5.6E-06	1.0E-06	1.4E-06	1.0E-06	1.0E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
780	2.0E-06	1.1E-06	2.0E-06	2.0E-06	1.5E-06	1.6E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
33A	5.7E-06	2.4E-06	1.5E-06	1.8-06	1.4E-06	1.4E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07
33B	5.3E-06	2.2E-06	1.5E-06	1.7E-06	1.3E-06	1.3E-06	9.9E-07	2.5E-07	1.2E-06	1.8E-06	1.1E-06	3.9E-07

Results of ARCON96 Calculation

- Used to determine the radiological hazards for facilities important to safety in preclosure operation of YMP
- Used in calculations to demonstrate conformance of the repository design to the performance objectives of the requirements of 10 CFR 63.111.
- Although 95th percentile χ/Q's are also calculated (for accident scenarios), only 50th percentiles (annual averages) are reported in Safety Analysis Report because Category 1 event sequence is excluded in preclosure operation by YMP performance requirements and sophisticated engineering design (conclusion from with PRA analysis and design)

Alternative of Dispersion Analysis for Onsite Receptors

- The flexibility of meteorological data input and statistically validated building wake/cavity algorithms allow reasonable estimate on onsite worker scenarios.
- The application of ARCON96 in YMP clearly demonstrates the merit for onsite worker safety analyses on a myriad of nuclear facility complex configurations and accident scenarios.
- ARCON96 is a tailored dispersion code for near-source with complex environment while MACCS2 is generic dispersion +…

Over-Conservatism of MACCS2

- Over-Conservatism in MACCS2 from simplified algorithms and generic equations for air dispersion
- The conservation become more significant for longer downwind distance, e.g., offsite receptors.
- Over-conservatism in dispersion analysis leads to overly conservative radiological dose, which may result in unreasonable control and/or mitigation cost.

Basic Equation for Ground-Level Release in MACCS2

$$\chi(x, y=0, z=0, H=0) = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} \left(1 + 2\sum_{n=1}^{5} \left\{ \exp\left[-2\left(\frac{nL}{\sigma_z} \right)^2 \right] \right\} \right)$$

Note:

1. The mixing layer term (in curly brackets) could be ignored for most LANL applications, especially for onsite receptors.

2. σ_y and σ_z are two critical parameters in estimating χ/Q.

Tadmor and Gur Equations (MACCS2 default)

$$\sigma_y(x) = a_i \; x^{b_i}$$

$$\sigma_z(x, z_0) = \left(\frac{z_0}{3\,cm}\right)^{0.2} c_i x^{d_i}$$

Notes: surface roughness z_0 at LANL = 38 cm

Stability Class	a_i	b_i	c_i	d_i
A	0.3658	0.9031	0.00025	2.125
B	0.2751	0.9031	0.0019	1.6021
C	0.2089	0.9031	0.2	0.8543
D	0.1474	0.9031	0.3	0.6532
E	0.1046	0.9031	0.4	0.6021
F	0.0722	0.9031	0.2	0.602

Direct Measurements of Dispersion Coefficients with Draxler Method

$$\sigma_y = \sigma_\theta x F_y\left(\frac{x}{\bar{u}t_y}\right) \approx \sigma_v t F_y\left(\frac{t}{t_y}\right)$$

$$\sigma_z = \sigma_\emptyset x F_z\left(\frac{x}{\bar{u}t_z}\right) \approx \sigma_w t F_z\left(\frac{t}{t_z}\right)$$

where

σ_v = S.D. of transverse or crosswind wind speed [m/s]

σ_w = S.D. of vertical wind speed at effective release height [m/s]

t = downwind traveling time [s] = x/u

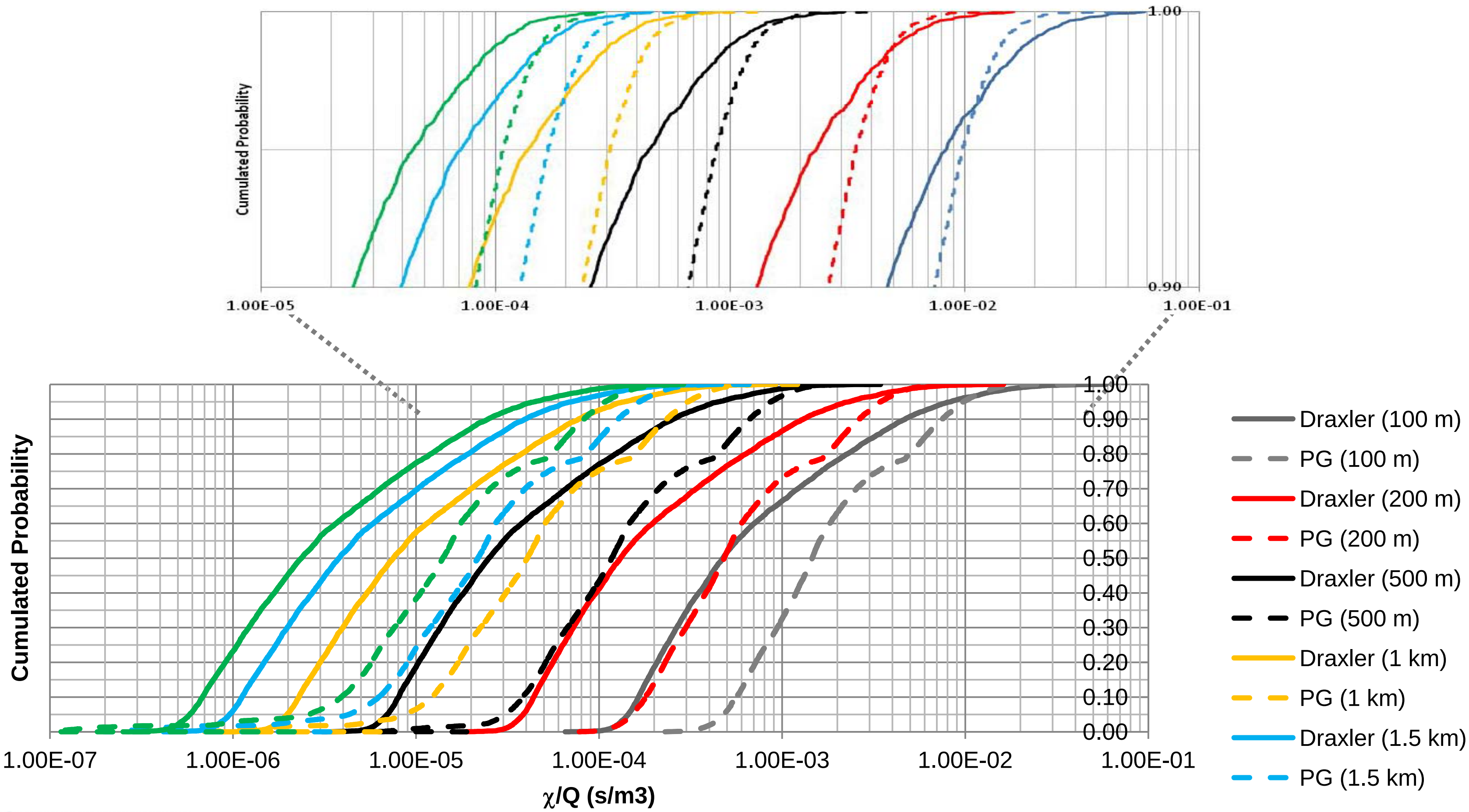
x = downwind distance at [m]

u = average downwind speed effective release height [m/s]

F_y = transverse universal function = $(1 + 0.90\sqrt{t/5000})^{-1}$ (Bowen 1994)

F_z = transverse universal function = $(1 + 0.90\sqrt{t/1000})^{-1}$ (Bowen 1994)

Cumulative Probability of χ/Q at Various Downwind Distances



Note: Based on TA6 2007 meteorological data

95^{th} Percentile χ/Q –Bowen vs. PG

Correlation	Downwind (m)					
	100	200	500	1000	1500	2000
Bowen/T-G	0.85	0.67	0.51	0.45	0.43	0.41
Bowen/T-G (Day)	0.44	0.38	0.31	0.29	0.28	0.28
Bowen/T-G (Night)	1.04	0.83	0.64	0.56	0.53	0.51

- The ratios can be considered as adjustment factors of the LANL site-specific turbulence to the generic turbulence conditions by MACCS2.
- For offsite receptors, MACCS2 over-predicts at least a factor of two.
- For day time offsite, the over-prediction by MACCS2 is > a factor of 3.
- The χ/Q ratios for 50^{th} percentile (annual average) are about 0.3 to 0.2 from 100 m to 2 km. Although overall 95^{th} percentile is reported in LANL safety basis analysis, the day time values are expected to be closer to reality due to LANL facilities are operated in daytime.

Alternative of Dispersion Analysis for Offsite Receptor

- For offsite general public, AERMOD could be a good candidate. AERMOD is a next generation air dispersion model based on planetary boundary theory, and is adopted by EPA as a preferred model since 2005.
- AERNOD improves the estimation of dispersion coefficients similar to the Draxler's formula discussed in this paper.
- In addition to advanced meteorological turbulence, AERMOD also includes the PRIME building downwash algorithms, advanced depositional parameters, and local terrain effects.
- Overall, the advanced capacity of AERMOD should provide better confidence in accuracy of offsite public doses and reduce unreasonably conservative control and mitigation cost.