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Dependence of TWRS FSAR X/Qs on Distance and Example Doses at Highway 240 with Stationary and Moving Receptors

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Abstract: A discussion of the reasons for the dependence of X/Q on receptor distance and compass sector is presented. In addition, X/Qs are calculated for three receptor scenarios on Highway 240 including a moving receptor. Example radiological doses and toxicological exposures at Highway 240 are calculated for two accidents already analyzed in the TWRS FSAR.

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DEPENDENCE OF TWRS FSAR X/Qs ON DISTANCE
AND EXAMPLE DOSES AT HIGH 240
WITH STATIONARY AND MOVING RECEPTORS

D.A. Himes
9/23/96

A discussion is presented on how the atmospheric dispersion parameter (receptor air concentration per unit release rate), X/Q , is calculated and where the sensitive dependence on receptor distance and the lesser dependence on wind direction sector originate. In addition, X/Q s are calculated for three receptor scenarios on State Highway 240, and corresponding radiological doses and toxicological exposures calculated for two example accidents already analyzed in the TWRS FSAR. The three receptor scenarios are: stopped for 2 hours; stopped for 12 hours; and driving through the plume at 45 mph (20.1 m/s). Details of the derivation of an effective time integrated X/Q for the moving receptor are included in attachment 1.

Variation of X/Q with distance:

The standard formulation of the steady-state X/Q for ground level releases and receptors on the plume centerline is given by

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z u} \quad (1)$$

where σ_y and σ_z are the horizontal and vertical dispersion coefficients, respectively (the same as the standard deviations for the corresponding gaussian distributions) and u is the wind speed. The sigmas are exponential functions of distance and are shown in the attached Figures 1 and 2. In the codes these parameters are actually calculated from standard formulas of the form $Ax^B + C$. The sigmas account for the lateral and vertical diffusion of material due to air turbulence as it travels downwind and are usually the dominant factors in the reduction of the X/Q with increasing distance. For Pasquill F atmospheric stability, for example, σ_y , σ_z and $1/(\sigma_y \sigma_z)$ are shown in Table 1 for a range of distances. These sigmas were calculated using the following formulas (PNL 1988):

$$\sigma_y = A_y x^{B_y} \quad (2)$$

where $A_y = 0.0722$ and $B_y = 0.9031$ for Pasquill stability class F, and

$$\sigma_z = A_z x^{B_z} + C_z \quad (3)$$

where $A_1 = 0.086$, $B_1 = 0.74$, and $C_1 = -0.35$ for $100 \text{ m} < x \leq 1000 \text{ m}$, and $A_2 = 18.05$, $B_2 = 0.18$, and $C_2 = -48.6$ for $x > 1000 \text{ m}$ for Pasquill stability class F.

Table 1: Dispersion parameters for Pasquill F

x (m)	$\sigma_y \sigma_z \text{ (m}^2\text{)}$	$1/(\sigma_y \sigma_z) \text{ (m}^{-2}\text{)}$
100	10.4	9.63E-2
200	34.5	2.90E-2
400	111	8.97E-3
600	220	4.55E-3
1000	515	1.94E-3
2000	1540	6.49E-4
4000	4100	2.44E-4
10000	13600	7.33E-5
20000	32500	3.08E-5

The resulting $1/(\sigma_y \sigma_z)$ is plotted in Figure 3 with the locations of the onsite receptor (100 m), the worst-case Highway 240 receptor, and the site boundary receptor shown. Note that the ratios of $1/(\sigma_y \sigma_z)$ for the onsite to the offsite receptors and the onsite to the Highway 240 receptor are 1100 and 420, respectively. Differences in the 99.5 percentile wind speed and atmospheric stability between sectors can have a considerable additional effect, but the dominant source of difference in X/Q between receptors at different distances is generally the dispersion coefficient's (σ_y and σ_z) dependence on distance.

Highway 240 X/Q:

State Highway 240 circles around the southwest corner of the 200 W Area through seven compass sectors. 99.5 percentile worst-case X/Qs were calculated for these sectors using the GXQ Code version 4.0A (Hey 1994) with the 1983 - 1991 average joint frequency meteorology table for the 200 areas at 10 m height (PNL 1993). The results are shown in Table 2.

Table 2: 99.5 percentile X/Qs at Highway 240

Sector	Distance (m)	Pasquill Atmos. Stability Class	Wind Speed Bin (m/s)	X/Q (s/m ³)
SSE (16)	4070	G	4.70	3.88E-5
S (1)	3520	E	0.89	4.69E-5
SSW (2)	3520	F	2.65	3.38E-5
SW (3)	3790	F	2.65	3.29E-5
WSW (4)	3890	F	2.65	3.19E-5
W (5)	4260	G	2.65	*6.56E-5*
WNW (6)	4810	G	4.70	3.17E-5

The X/Qs in these sectors were calculated over a distance range of 100 m to 10 km and are shown in Figure 4 to show typical effects of the variation of worst-case wind speed and stability class with sector which is superimposed on the rapid decrease with distance due to the increase in $\sigma_y \sigma_z$. The GXQ run file for this parametric calculation as well as the cases shown in Table 2 are included as Attachment 2. Note that the west sector has the highest X/Q even though the receptor in that sector is not the closest to the release point. The higher position of the west sector plot in Figure 4 is due to the combined effects of the extremely stable (Pasquill G) condition and the low wind speed being worst-case in that sector.

Note that the corresponding site boundary receptor (8760 m N) X/Q is $2.83E-5$ s/m^3 . Given the same uptake scenario, therefore, the highway 240 receptor would receive $6.56E-5 / 2.83E-5 = 2.32$ times the site boundary dose. In like manner, the toxicological sums of fractions could be multiplied by the same factor (for a stationary receptor).

Examples of dose calculations for Highway 240:

Several example calculations were performed for exposures to the Highway 240 receptor for two accidents already analyzed in the TWRS FSAR. The accidents are the "Spray Leak In Structure or From Overground Waste Transfer Lines" (mitigated case) and the "Organic Salt-Nitrate Reaction" (0.92 m^3 reaction volume). Three scenarios were analyzed for radiological and toxicological consequences:

1. Car travelling on Highway 240 at 45 mph through the plume.
2. Car stopped for 2 hours in the plume.
3. Car stopped for 12 hours in the plume.

The standard model for radiological dose rate (D') to a receptor can be given in the form

$$D' = R' \frac{X}{Q} (BR) (ULD) \quad (4)$$

Where R' is the Release rate (L/s), BR is the assumed light activity breathing rate ($3.3E-4$ m^3/s), and ULD is the unit liter dose for the material released (Sv/L). For stationary receptors on the plume centerline, the dose is then just proportional to the X/Q. For a moving receptor, however, an effective X/Q must be formulated which produces the proper time-integrated dose as the receptor traverses the plume. The X/Q for a receptor which is offset by a distance y from the plume centerline is given by

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \quad (5)$$

Assuming that the car travels through the width of the plume in a direction perpendicular to the plume axis, it is easy to show from Eqns. 4 and 5 (see attachment 1) that the total dose incurred by this receptor is given by

$$D = R' \frac{\Psi}{Q} (BR) (ULD) \quad (6)$$

where

$$\frac{\Psi}{Q} = \frac{\sqrt{2}}{\sqrt{\pi} \sigma_z u v} \quad (7)$$

where v is the speed of the car (m/s). Resulting values of Ψ/Q at highway 240 for the sectors and distances shown in Table 2 are shown in Table 3.

Table 3: Effective time-integrated dispersion coefficient for a receptor with a speed of 45 mph transverse to the plume axis on Highway 240

Sector	Distance (m)	Stability Class	σ_z (m)	Wind Speed (m/s)	Ψ/Q (s^2/m^3)
SSE (16)	4070	G	19.1	4.70	4.41E-4
S (1)	3520	E	47.2	0.89	*9.45E-4*
SSW (2)	3520	F	29.9	2.65	5.01E-4
SW (3)	3790	F	30.9	2.65	4.84E-4
WSW (4)	3890	F	31.3	2.65	4.78E-4
W (5)	4260	G	19.5	2.65	7.67E-4
WNW (6)	4810	G	20.6	4.70	4.10E-4

The highest exposures by the moving receptor are indicated to occur in the south sector (dominant effect here is the low worst-case windspeed). The σ_z s in Table 3 were calculated using Eqn. 3 (for $x > 1000$ m) with $A_x = 10.83$, $B_z = 0.18$, and $C_z = -29.2$ for Pasquill G, $A_z = 18.05$, $B_z = 0.18$, and $C_z = -48.6$ for Pasquill F, and $A_z = 6.73$, $B_z = 0.305$ and $C_z = -34$ for Pasquill E (PNL 1988). The traverse times required to cross the plume are shown in Table 3 for the S sector above. The σ_y for this case is 167 m at the receptor distance of 3520 m ($A_y = 0.1046$ and $B_y = 0.9031$ for Pasquill E stability [PNL 1988]). Note that the transverse diffusion coefficient, σ_y , is measured from the plume centerline so that the actual traversed plume width is doubled.

Table 4: Plume traverse times

Traversed Width (m)	Traverse Time (s)	% of Material Traversed
$1\sigma_y \times 2$	16.6	68.3
$2\sigma_y \times 2$	33.2	95.7
$3\sigma_y \times 2$	49.8	99.7

It will also be useful to note that if the total amount of material in the transverse Gaussian distribution (which theoretically extends from $y = -\infty$ to $+\infty$) were to be packed into a y interval such that the concentration is uniform and equal to the maximum concentration at the plume centerline, The width of this y interval would be $(2\pi)^{1/2}\sigma_y$. The time required to cross this effective plume width at 45 mph is then just $(2\pi)^{1/2}(16.6 \text{ s}/2) = 20.8 \text{ s}$.

==> Spray Leak - radiological:

The ULD for this material (AWF 33% solids - 67% liquids) is $5.6\text{E}+5 \text{ Sv/L}$. The release rate during the first 15 minutes of the accident is $6.22\text{E}-6 \text{ L/s}$. The maximum value of Ψ/Q is shown in Table 3 for the south sector as $9.45\text{E}-4$. The speed of the car is 20.1 m/s (45 mph). Applying Eqn. 6, the resulting dose to the moving receptor is $1.09\text{E}-6 \text{ Sv}$ ($1.09\text{E}-4 \text{ rem}$).

For this accident, there is a dose associated with the first hour of exposure and a second additive dose associated with the next 11 hours of exposure. The two-hour dose to the stationary receptor was therefore calculated by adding the first hour of onsite dose ($3.6\text{E}-2 \text{ Sv}$) to 1/11 of the 11 hour onsite dose ($3.8\text{E}-3 \text{ Sv}$) and multiplying by the ratio of the Highway 240 X/Q to the onsite X/Q ($6.56\text{E}-5/3.41\text{E}-2$) to yield $6.99\text{E}-5 \text{ Sv}$ ($6.99\text{E}-3 \text{ rem}$). The 12 hour dose was just the total onsite dose multiplied by the same X/Q ratio to yield $7.70\text{E}-5 \text{ Sv}$ ($7.70\text{E}-3 \text{ rem}$).

==> Spray Leak - Toxicological:

The site boundary composite sum of fractions multiplier for this material is 68 s/L . The composite sum of fractions multiplier at the Highway 240 receptor would then be just the site boundary value multiplied by the ratio of the corresponding X/Q_s , i.e., $(6.56\text{E}-5/2.83\text{E}-5)(68 \text{ s/L}) = 158 \text{ s/L}$.

For the plume traverse, the effective width of the plume at a constant concentration equal to the maximum plume centerline concentration is $(2\pi)^{1/2}\sigma_y$ and, as previously discussed, the time required to traverse this distance in the worst sector is 20.8 s . The 1 minute average sum of fractions incurred by the moving receptor during plume traverse is then $(6.22\text{E}-6 \text{ L/s})(158 \text{ s/L})(20.8 \text{ s}/60 \text{ s}) = 3.41\text{E}-4$.

For the 2 hour and 12 hour Highway 240 receptors the sum of fractions would just be the Highway 240 sum of fractions multiplier multiplied by the release rate or $(158 \text{ s/L})(6.22\text{E-}6 \text{ L/s}) = 9.83\text{E-}4$.

==> Organic Nitrate-Salt Reaction - Radiological:

The peak release rate for this accident occurs at about 1000 s into the accident. The width of the release rate peak is small but is comparable to the time required for the receptor to traverse the plume (about 30 s) so the peak release rate was used. It is estimated that the average release rate over the 1010 s release time is about 40% of the peak release rate. The maximum release rate for the i th isotope (Bq/s) is then given by

$$R'_i = \frac{1}{0.4} \left[\frac{V}{1010\text{s}} (RF_i Q_i) (1000 \frac{\text{L}}{\text{m}^3}) \right] \quad (8)$$

where V is the tank waste volume (m^3) and RF_i and Q_i are the release fraction and the waste concentration for the i th isotope, respectively. Eqn. 6 in the form

$$D_i = R'_i \frac{\Psi}{Q} (BR) (DCF_i) \quad (9)$$

where DCF_i is the dose conversion factor for the i th isotope (Sv/Bq) can then be used to calculate the integrated dose for the i th isotope. Eqn. 9 must be summed over the isotopes in the mix. Dose conversion factors, release fractions, and concentrations for the significant isotopes in the mix were taken from draft Appendix C of WHC-SD-WM-SARR-033 Rev 1 and are shown in Table 5. The tank waste volume, V , is 1582 m^3 .

Table 5: Dose conversion factors, release fractions, and concentrations used in Eqns. 8 and 9

Isotope	DCF _i (Sv/Bq)	RF _i	Q _i (Bq/L)	DCF _i RF _i Q _i (Sv/L)
Cs-137	8.63E-9	3.6E-5	1.01E+11	3.14E-2
Sr-90	6.47E-8	1.5E-12	1.63E+12	1.58E-7
Y-90	2.28E-9	4.9E-14	1.63E+12	1.82E-10
Co-60	5.91E-8	1.6E-12	4.18E+8	3.95E-11
Tc-99	2.25E-9	5.5E-12	1.20E+10	1.49E-10
Sb-125	3.30E-9	3.4E-6	2.80E+8	3.14E-6
Eu-154	7.73E-8	3.9E-7	5.75E+9	1.73E-4
Pu-239	1.16E-4	5.5E-14	4.40E+8	2.81E-9
				$\Sigma = 3.16\text{E-}2$

From Table 3 the maximum value of Ψ/Q is $9.45E-4 \text{ s}^2/\text{m}^3$. Combining Eqns. 8 and 9 and using the last column of Table 5 yields the dose incurred in traversing the plume at 45 mph as $3.86E-5 \text{ Sv}$ ($3.86E-3 \text{ rem}$).

Since the release time is less than 1 hour, the 2 hour and 12 hour highway 240 doses are the same and can be calculated using the onsite dose (0.577 Sv) along with the X/Q ratio ($6.56E-5/3.41E-2$) as previously discussed. The resulting dose is $1.11E-3 \text{ Sv}$ ($1.11E-1 \text{ rem}$) for both the 2 hour and the 12 hour exposures.

=> Organic Nitrate-Salt Reaction - Toxicological

The sums of fractions (SOF) in the accident analysis are based on a release rate averaged over the 1010 s release time. As before, the average release rate is estimated to be about 40% of the peak release rate. Basing the SOF on the peak release rate will therefore produce an increase by a factor of $1/0.4 = 2.5$.

As previously discussed, the time required to traverse the effective width of a plume with a constant concentration equal to the peak centerline value is 20.8 s at 45 mph. Averaging the exposure over 15 minutes (dominant material is Hg which is a cumulative toxin) will therefore produce a reduction in the SOF of $20.8 \text{ s}/900 \text{ s} = 2.31E-2$. Finally, moving the receptor from the site boundary to Highway 240 will produce an increase by a factor 2.32, the ratio of the X/Q s.

The net Highway 240 sum of fractions for a given limit category is then given by the corresponding site boundary value (given for a range of limit categories in the safety analysis) times the factor $(2.5)(2.31E-2)(2.32) = 1.34E-1$ for the plume transit at 45 mph.

For the 2 hour and 12 hour stationary Highway 240 receptors, the sum of fractions for a given limit category would just be the site boundary sum of fractions multiplied by 2.32.

Summary:

The variation of X/Q with receptor distance was found to be primarily due to the changes in the diffusion parameters σ_y and σ_z . However differences in the effective Pasquill stability class and wind speed derived from historical meteorological records for different compass sectors can also have a considerable effect. For Pasquill stability class F, for example, the non-directionally dependent variations in σ_y and σ_z with distance produced ratios of the onsite to the offsite receptor X/Q s and the onsite to the Highway 240 receptor X/Q s of 1100 and 420, respectively. Typical variations produced by differences in atmospheric stability and wind speed between sectors are on the order of factors of 2 or 3 at a given distance.

The 99.5 percentile X/Q was calculated for ground level releases in the tank farms and a stationary receptor on Highway 240. The worst location on Highway 240 was 4260 m west of the 200 W tank farms with a X/Q of $6.56E-5 \text{ s}/\text{m}^3$. Using

a simple X/Q ratio, it was determined that the Highway 240 radiological doses or toxicological sums of fractions (SOF) (for a stationary receptor only) would be a factor 2.32 times higher than the site boundary doses.

Highway 240 doses and SOFs were evaluated for two previously analyzed accidents (Spray Leak In Structure and Organic Nitrate-Salt Reaction). Three receptor scenarios were considered: car moving through plume at 45 mph; car stopped for 2 hours; and car stopped for 12 hours. The results are summarized in Tables 6 and 7 below.

Table 6: Radiological doses to receptor on Highway 240

Accident	Car Moving At 45 mph	Car Stopped For 2 hours	Car Stopped For 12 hours
Spray Leak In Structure	1.1E-3 mSv (1.1E-4 rem)	7.0E-2 mSv (7.0E-3 rem)	7.7E-2 mSv (7.7E-3 rem)
Organic Nitrate- Salt Reaction	3.9E-2 mSv (3.9E-3 rem)	1.1E+0 mSv (1.1E-1 rem)	1.1E+0 mSv (1.1E-1 rem)

Table 7: Toxicological sums of fractions (SOF) at Highway 240

Accident	Car Moving At 45 mph	Car Stopped For 2 hours	Car Stopped For 12 hours
Spray Leak In Structure	3.4E-4	9.8E-4	9.8E-4
Organic Nitrate- Salt Reaction	*Site Boundary SOF x 0.134	*Site Boundary SOF x 2.32	*Site Boundary SOF x 2.32

* SOFs are given for a range of limit categories in the safety analysis

References:

- Hey 1994, B.E. Hey, *GXQ Program User's Guide*, WHC-SD-GN-SWD-30002, Rev. 1, December 1994.
- PNL 1988, B.A. Napier, D.L. Streng, R.A. Peloquin, and J.V. Ramsdell, *GENII - The Hanford Environmental Radiation Dosimetry Software System*, Pacific Northwest Laboratory, PNL-6584, December 1988.
- PNL 1993, R.G. Schreckhise, K. Rhoads, J.S. Davis, B.A. Napier, and J.V. Ramsdell, *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters*, Hanford Environmental Dose Overview Panel, PNL 3777 Rev 2, April 1993.

Figure 1: σ_y PlotFig. 3.10—Lateral diffusion, σ_y , vs. downwind distance from source for Pasquill's turbulence types.

and Bryant (1964) have also employed these values of σ in plume diffusion analyses.

Sections 4-4.3 and 4-4.4 of Chap. 4 indicate that Pasquill's curves fit the experimental data collected since the Prairie Grass experiments quite well. Furthermore the experimental data discussed in these sections demonstrate that the standard deviation of the horizontal wind direction, σ_θ , for a short averaging time and for the sampling times used in these experiments (10 min to 60 min) can be related empirically to the measured values of plume width or to normalized average concentration or exposure from continuous sources. On the basis of these data, Pasquill's stability categories

can be relabeled approximately in terms of measured values of σ_θ as follows:

Pasquill stability categories	σ_θ
A, extremely unstable	25.0°
B, moderately unstable	20.0°
C, slightly unstable	15.0°
D, neutral	10.0°
E, slightly stable	5.0°
F, moderately stable	2.5°

Pasquill's method of estimating diffusion is well suited to field use because a simple recording wind vane and anemometer erected at a proposed site can, when used with the wind-direction range theory (Chap. 2, Sec. 2-6.2.3),

Figure 2: σ_z PlotFig. 3.11 — Vertical diffusion, σ_z , vs. downwind distance from source for Pasquill's turbulence types.

furnish climatologically useful estimates of σ_θ rapidly. Only simple manual data processing is necessary. The wind-measuring system will, moreover, furnish data for other climatological wind statistics for the site, such as wind roses, and will also serve as the necessary wind-velocity monitoring equipment for permanent installation when the reactor or other plant is in operation.

3-3.4.2 Quantitative Use of Smoke Observations to Determine Diffusion Coefficients. Visual and photographic observations of smoke plumes and puffs have always appealed to workers in atmospheric diffusion as a useful research tool. Characteristically Richardson (1920) worked

with time-exposure photographs of smoke puffs very early in the history of diffusion study. The use of smoke as a diffusion index continues to be widespread to this day. Quantitative interpretations of smoke observations (Sutton, 1932, Holland, 1953, Kellogg, 1956, Frenkiel and Katz, 1956, Gifford, 1957, 1959, Saissac, 1958, Inoue, 1960, and Högström, 1964) have usually exploited Roberts' (1923) opacity theory in which the visible edge of the smoke plume or puff is supposed to represent a constant threshold density of smoke particles along the line of sight.

The total density of smoke particles is obtained, according to the opacity idea, by integration of the concentration-distribution equa-

Figure 3: $1/(\sigma_y \sigma_z)$ for Pasquill F Stability

Figure 4: 99.5 Percentile X/Q from Tank Farms to Highway 240

467400
($\frac{s}{m^3}$)
 $\frac{X}{Q}$

LOGARITHMIC 3.3 CYCLES
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Attachment 1
Derivation of Ψ/Q for a Moving Receptor

Derivation of Ψ/Q for a Moving Receptor Traveling Transverse to the Plume Axis

The standard model for radiological dose rate (D') to a receptor can be given in the form

$$D' = R' \frac{X}{Q} (BR) (DCF) \quad (1-1)$$

Where R' is the Release rate (Ci/s , L/s , etc.), BR is the assumed light activity breathing rate ($3.3\text{E-}4 \text{ m}^3/\text{s}$), and DCF is a dose conversion factor for the material released (Sv/Ci , Sv/L , etc.). For stationary receptors on the plume centerline, the dose is then just proportional to the X/Q . For a moving receptor, however, an effective X/Q must be formulated which produces the proper time-integrated dose as the receptor traverses the plume. The X/Q for a receptor which is offset by a distance y from the plume centerline is given by

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z u} \exp\left(-\frac{y^2}{2 \sigma_y^2}\right) \quad (1-2)$$

Assuming that the car travels through the width of the plume in a direction perpendicular to the plume axis at a constant speed, v , such that the car crosses the plume axis at time $t = 0$, then $y = vt$, and

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z u} \exp\left(-\frac{v^2 t^2}{2 \sigma_y^2}\right) \quad (1-3)$$

From Eqn. 1-1 the maximum total dose which is incurred by a receptor driving transversely through the plume assuming a constant release rate R' is given by

$$D = \int_{-\infty}^{+\infty} D' dt = (BR) (DCF) R' \int_{-\infty}^{+\infty} \frac{X}{Q} dt \quad (1-4)$$

The integral on the right side of Eqn. 1-4 is easily evaluated to yield an integrated exposure per unit release for the moving receptor as follows:

$$\frac{\Psi}{Q} = \frac{1}{\pi \sigma_y \sigma_z u} \int_{-\infty}^{+\infty} \exp\left(-\frac{v^2 t^2}{2 \sigma_y^2}\right) dt = \frac{\sqrt{2}}{\sqrt{\pi} \sigma_z u v} \quad (1-5)$$

The total dose during plume traverse is then

$$D = R' \frac{\Psi}{Q} (BR) (ULD) \quad (1-6)$$

Alternatively, the total dose can be evaluated as a peak dose rate times an effective time of exposure using Eqns. 1 and 4 as follows.

$$D = (BR) (DCF) R' \frac{1}{\pi \sigma_y \sigma_z u} t \quad (1-7)$$

For a Gaussian plume the effective width of a transverse interval containing the same total amount of material at a uniform concentration equal to the maximum centerline concentration is $(2\pi)^{1/2} \sigma_y$. The effective traverse time shown in Eqn. 1-7 is then $t = (2\pi)^{1/2} \sigma_y / v$ where v is the speed of the car across the plume. The resulting total dose is then just

$$D = (BR) (DCF) R' \frac{\sqrt{2\pi} \sigma_y}{\pi \sigma_y \sigma_z u v} = (BR) (DCF) R' \frac{\sqrt{2}}{\sqrt{\pi} \sigma_z u v} \quad (1-8)$$

as before.

Attachment 2
GXQ Runfiles for Highway 240 X/Qs

GXQ Version 4.0A
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.

Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.

Code Custodian is: Brit E. Hey
Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352
(509) 376-2921

Run Date = 09/16/96
Run Time = 15:47:30.24

INPUT ECHO:
TWRS - Highway 240 parametric

c GXQ Version 4.0 Input File

c mode
1

c

c MODE CHOICE:

c mode = 1 then X/Q based on Hanford site specific meteorology

c mode = 2 then X/Q based on atmospheric stability class and wind speed

c mode = 3 then X/Q plot file is created

c

c LOGICAL CHOICES:

c ifox inorm icdf ichk isite ipop
T F F F F F

c ifox = t then joint frequency used to compute frequency to exceed X/Q

c = f then joint frequency used to compute annual average X/Q

c inorm = t then joint frequency data is normalized (as in GENII)

c = f then joint frequency data is un-normalized

c icdf = t then cumulative distribution file created (CDF.OUT)

c = f then no cumulative distribution file created

c ichk = t then X/Q parameter print option turned on

c = f then no parameter print

c isite = t then X/Q based on joint frequency data for all 16 sectors

c = f then X/Q based on joint frequency data of individual sectors

c ipop = t then X/Q is population weighted

c = f then no population weighting

c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c ipuff idep isrc iwind
c 0 0 0 0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c iwake ipm iflow ientr
c 0 0 0 0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c (irise igrnd)iwash igrav
c 0 0 0 0
c ipuff = 1 then X/Q calculated using puff model
c = 0 then X/Q calculated using default continuous plume model
c idep = 1 then plume depletion model turned on (Chamberlain model)
c isrc = 1 then X/Q multiplied by scalar
c = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c = 2 then MACCS virtual distance building wake model turned on
c ipm = 1 then NRC RG 1.145 plume meander model turned on
c = 2 then 5th Power Law plume meander model turned on
c = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
c igrav = 1 then gravitational settling model turned on
c = 0 unless specified otherwise, 0 turns model off
c

c PARAMETER INPUT:

c	release	reference	mixing	frequency
c	height	anemometer	height	to
c	hs(m)	height	height	exceed
c		ha(m)	hm(m)	Cx(%)
c	0.00000E+00	1.00000E+01	1.00000E+03	5.00000E-01
c	initial	initial		
c	plume	plume	release	deposition
c	width	height	duration	velocity
c	Wb(m)	Hb(m)	trd(hr)	vd(m/s)
c	0.00000E+00	0.00000E+00	1.00000E+00	1.00000E-03
c				1.00000E-03
c		initial	initial	convective
c	ambient	plume	plume	heat release
c	temperature	temperature	flow rate	diameter
c	Tamb(C)	TO(C)	VO(m3/s)	d(m)
c				qh(w)
c	2.00000E+01	2.00000E+01	1.00000E+00	1.00000E+00
c				0.00000E+00

c (1) If zero then buoyant flux based on plume/ambient temperature difference.

```

c
c X/Q          Wind
c scaling      Speed
c factor       Exponent
c c(?)        a(?)
c
c 1.00000E+00  7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE      make      RECEPTOR DEPENDENT DATA
c 1 (site specific)  sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file) class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

```

MODE:

Site specific X/Q calculated.

LOGICAL CHOICES:

Joint frequency used to calculate X/Q based on frequency of exceedance.

No normalization of joint frequency.

X/Q calculated for single sector.

MODELS SELECTED:

Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:

200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)

Created 8/26/92 KR

TWRS - Highway 240 parametric

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
SSE	100	0	4.78	1	1.58E-02	1.58E-02	G	4.70
SSE	500	0	4.78	1	1.00E-03	1.00E-03	G	4.70
SSE	1000	0	4.78	1	3.19E-04	3.19E-04	G	4.70
SSE	4070	0	4.78	1	3.88E-05	3.88E-05	G	4.70
SSE	5000	0	4.78	1	2.92E-05	2.92E-05	G	4.70
SSE	10000	0	4.78	1	1.16E-05	1.16E-05	G	4.70
S	100	0	6.30	1	1.56E-02	1.56E-02	E	0.89
S	500	0	6.30	1	9.91E-04	9.91E-04	E	0.89
S	1000	0	6.30	1	3.16E-04	3.16E-04	E	0.89
S	3520	0	6.30	1	4.69E-05	4.69E-05	E	0.89
S	5000	0	6.30	1	2.88E-05	2.88E-05	E	0.89
S	10000	0	6.30	1	1.14E-05	1.14E-05	E	0.89
SSW	100	0	4.53	1	1.13E-02	1.13E-02	F	2.65
SSW	500	0	4.53	1	7.21E-04	7.21E-04	F	2.65
SSW	1000	0	4.53	1	2.27E-04	2.27E-04	F	2.65
SSW	3520	0	4.53	1	3.38E-05	3.38E-05	F	2.65
SSW	5000	0	4.53	1	2.10E-05	2.10E-05	F	2.65
SSW	10000	0	4.53	1	7.06E-06	7.06E-06	F	2.65
SW	100	0	2.93	1	1.21E-02	1.21E-02	F	2.65
SW	500	0	2.93	1	7.75E-04	7.75E-04	F	2.65
SW	1000	0	2.93	1	2.45E-04	2.45E-04	F	2.65
SW	3790	0	2.93	1	3.29E-05	3.29E-05	F	2.65
SW	5000	0	2.93	1	2.26E-05	2.26E-05	F	2.65
SW	10000	0	2.93	1	9.10E-06	9.10E-06	F	2.65
WSW	100	0	2.72	1	1.22E-02	1.22E-02	F	2.65
WSW	500	0	2.72	1	7.78E-04	7.78E-04	F	2.65
WSW	1000	0	2.72	1	2.46E-04	2.46E-04	F	2.65
WSW	3890	0	2.72	1	3.19E-05	3.19E-05	F	2.65
WSW	5000	0	2.72	1	2.27E-05	2.27E-05	F	2.65
WSW	10000	0	2.72	1	9.13E-06	9.13E-06	F	2.65
W	100	0	4.80	1	2.80E-02	2.80E-02	G	2.65
W	500	0	4.80	1	1.79E-03	1.79E-03	G	2.65
W	1000	0	4.80	1	5.65E-04	5.65E-04	G	2.65
W	4260	0	4.80	1	6.56E-05	6.56E-05	G	2.65
W	5000	0	4.80	1	5.29E-05	5.29E-05	G	2.65
W	10000	0	4.80	1	2.14E-05	2.14E-05	G	2.65
WNW	100	0	3.98	1	1.60E-02	1.60E-02	G	4.70
WNW	500	0	3.98	1	1.02E-03	1.02E-03	G	4.70
WNW	1000	0	3.98	1	3.23E-04	3.23E-04	G	4.70
WNW	4810	0	3.98	1	3.17E-05	3.17E-05	G	4.70
WNW	5000	0	3.98	1	3.01E-05	3.01E-05	G	4.70
WNW	10000	0	3.98	1	1.21E-05	1.21E-05	G	4.70

CHECKLIST FOR PEER REVIEW

Document Reviewed: **DEPENDENCE OF TWRS FSAR X/Qs ON DISTANCE AND EXAMPLE DOSES AT HIGHWAY 240 WITH STATIONARY AND MOVING RECEPTORS,**
D.A. Himes, 9/23/96

Scope of Review: entire document

Yes	No	NA	
☒	☐	☐	* Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☒	☐	☐	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☒	☐	☐	Software input correct and consistent with document reviewed.
☒	☐	☐	Software output consistent with input and with results reported in document reviewed.
☐	☐	☒	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☐	☐	☒	Format consistent with appropriate NRC Regulatory Guide or other standards
☐	☐	☒	* Review calculations, comments, and/or notes are attached.
☒	☐	☐	Document approved.

J.C. Van Keuren
Reviewer (Printed Name and Signature)

10/2/96
Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

HEDOP REVIEW CHECKLIST
for
Radiological and Nonradiological Release Calculations

Document reviewed (include title or description of calculation, document number, author, and date, as applicable):

DEPENDENCE OF TWRS FSAR X/Qs ON DISTANCE AND EXAMPLE DOSES AT HIGHWAY 240 WITH STATIONARY AND MOVING RECEPTORS, D.A. Himes, 9/23/96

Submitted by: D.A. Himes

Date Submitted:

Scope of Review: entire document

YES NO* N/A

☒	☐	☐	1. A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
☐	☐	☒	2. Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
☐	☐	☒	3. HEDOP-approved code(s) were used.
☐	☐	☒	4. Receptor locations were selected according to HEDOP recommendations.
☒	☐	☐	5. All applicable environmental pathways and code options were included and are appropriate for the calculations.
☒	☐	☐	6. Hanford site data were used.
☒	☐	☐	7. Model adjustments external to the computer program were justified and performed correctly.
☐	☐	☒	8. The analysis is consistent with HEDOP recommendations.
☐	☐	☒	9. Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
☒	☐		10. Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.

* All "NO" responses must be explained and use of nonstandard methods justified.

Brian E. Hey [Signature] 10/4/96
HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):

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To	From	Page 1 of 1			
Distribution	D.A. Himes	Date 9/30/96			
Project Title/Work Order		EDT No. 619413			
Dependence of TWRS FSAR X/Qs on Distance and Example Doses at Highway 240 with Stationary and Moving Receptors		ECN No. N/A			
Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
C. Carro	A2-34	X			
M.L. Cowen	A2-34	X			
B.E. Hey	A3-34	X			
D.A. Himes (2)	A3-34	X			
D.S. Leach	A3-34	X			
J.C. Van Keuren	A3-34	X			
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