Erosion Modeling Issues that Need Attention and Sensitivity Analyses

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West Valley Citizen Task Force meeting
June 28, 2017

Erosion Modeling Issues that Need Attention and Sensitivity Analyses

1. Principal causes of erosion, and erosion's central importance to risk, are being pushed aside or severely diluted by other "bells and whistles" in the modeling work
2. Channelized flow in Erdman Brook watershed has been (and is still being?) modeled incorrectly
3. Using Franks Creek watershed (rather than Buttermilk Creek watershed) as the modeled area will apparently reduce the robustness of the model and its results
4. Ten-year time steps for the model runs are much too long unless many identical model runs are conducted
5. Modeling runs are apparently using incorrect rainfall intensity-frequency (RIF) distributions

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Principal causes of erosion, and erosion's central importance to risk, are being pushed aside or severely diluted by other "bells and whistles" in the modeling work

- We know from comparing 1996 DEIS to 2010 EIS that different erosion modeling assumptions can change receptor dose by as much as a factor of 75,000
- No other relevant variable has an effect this large – as sensitivity analysis would show
- Running multiple models, as currently planned, is not helpful if the same erroneous data or subroutines are being used for all models
- "Bells & whistles": Python code, Jupyter Notebook, Dakota package (sensitivity analysis), Landlab Toolkit, some of the PPA modeling assumptions & priorities

Erosion's central importance to risk is being pushed aside or severely diluted by other "bells and whistles" in the modeling work

- We know from comparing 1996 DEIS to 2010 EIS that different erosion modeling assumptions can change receptor dose by as much as a factor of 75,000
- Factor of 75,000 = 300,000 mrem/yr / 4 mrem/yr
- …where 300,000 mrem/yr was peak dose in 1996 DEIS, and 4 mrem/yr is peak dose in 2010 EIS (Table 2-4) for Cattaraugus Creek and SNI receptors for the *close-in-place alternative*, assuming unmitigated erosion
- Compare also *the serious breaching of burial grounds in 1996 DEIS* to absence of such breaching in 2010 EIS

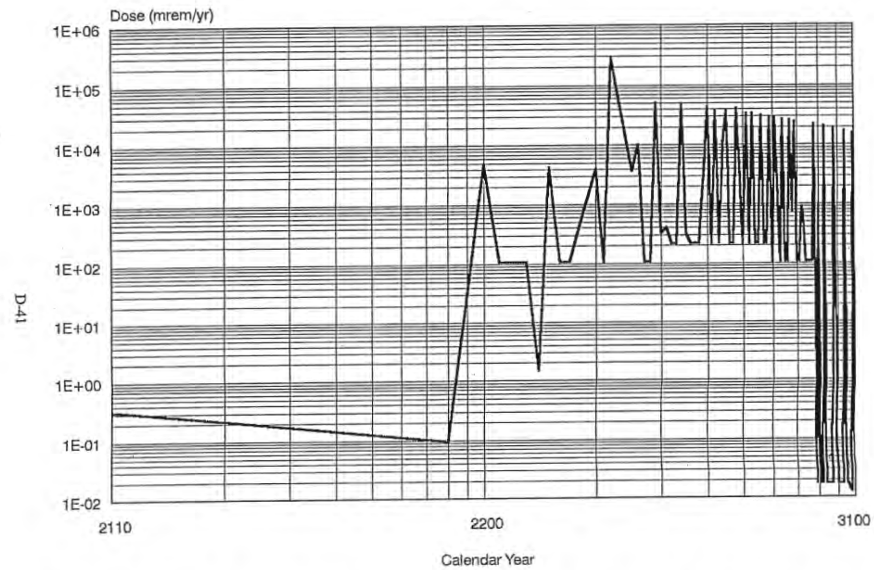
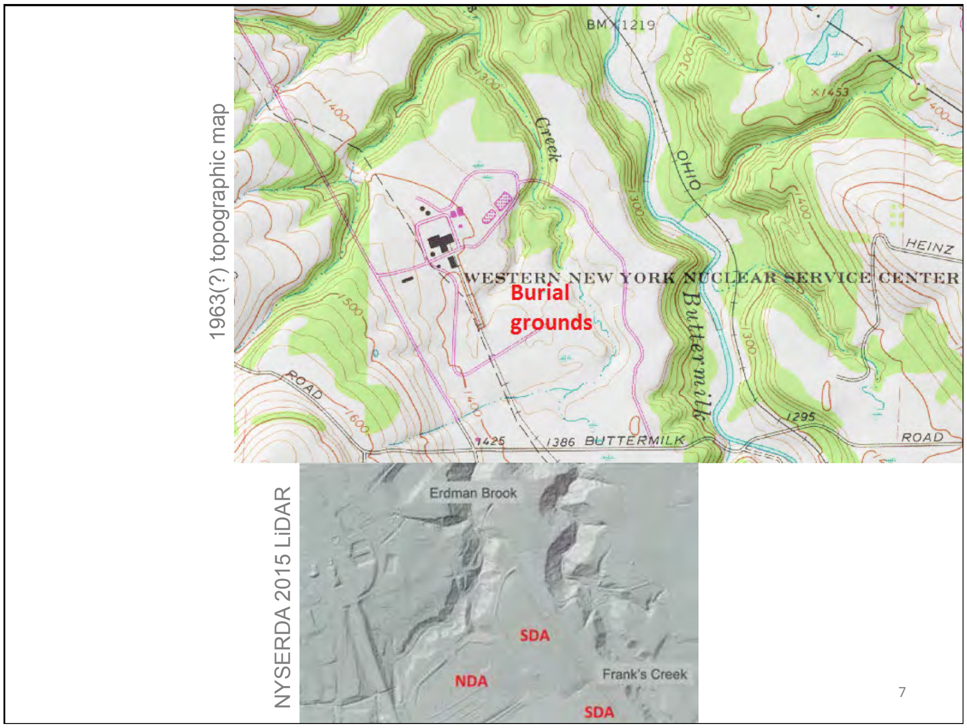


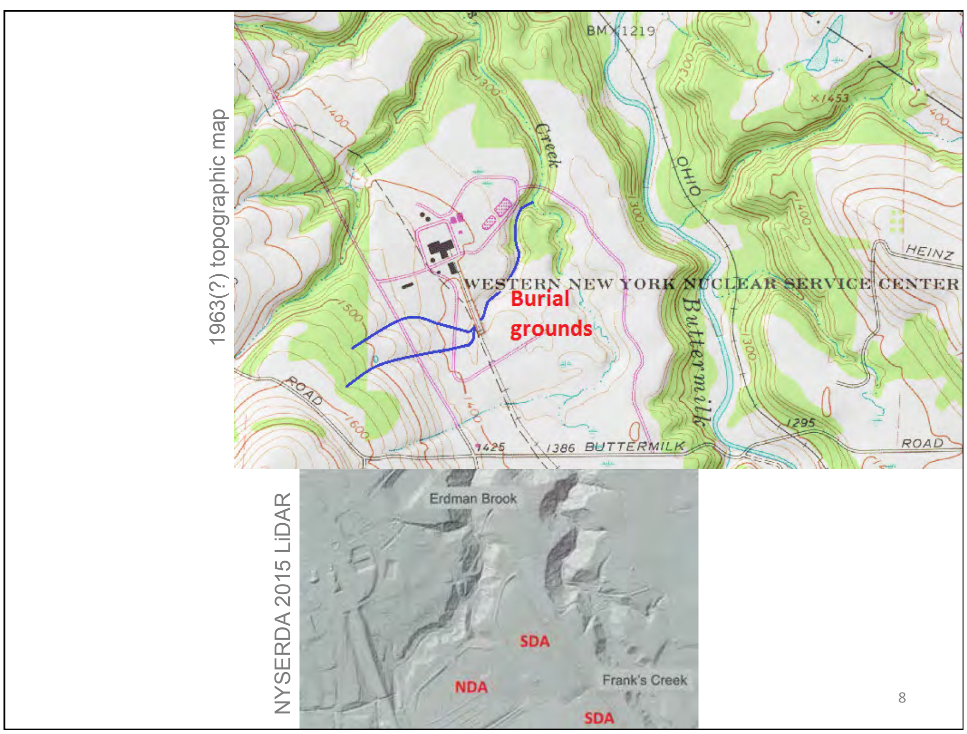
Figure D-8. **Alternative III Assumed Loss of Institutional Control Case, Local Erosion Control Strategy: Erosion Collapse Scenario, Cumulative Impacts for a Buttermilk Creek Resident**

Source: DOE 1996 West Valley DEIS, DOE/EIS-0226D, Appendix D, page D-41 5

Channelized flow in Erdman Brook watershed has been (and is still being?) modeled incorrectly

- **Headwaters of Erdman Brook descend hillside west of Rock Springs Road, partly as channelized flow (see esp. 1963? topo map) which formerly continued directly into Erdman Brook channel between North & South plateaus**
- **Culverts carry this flow under road & rail embankments**
- **Modeling done for 2010 EIS *apparently didn't recognize culverts* and effectively treated embankment(s) as check dam(s) – a well-known way to reduce erosion**
- **Current modeling apparently simulates culverts as thin slots in embankment(s), which is better – and note that thin slots will tend to widen due to erosion**
- **A consistent, realistic approach is needed!** 6


1963(?) topographic map
NYSERDA 2015 LiDAR
BM 1219
Creek
OHIO
HEINZ
WESTERN NEW YORK NUCLEAR SERVICE CENTER
Burial
grounds
Buttermilk
ROAD
1295
1425
1386 BUTTERMILK
ROAD
Erdman Brook
SDA
NDA
Frank's Creek
SDA
7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8

Using Franks Creek watershed (rather than Buttermilk Creek watershed) as the modeled area will apparently reduce the robustness of the model and its results

- Choice of Franks Creek watershed as the modeled area was announced about halfway through the May 10th pre-QPM meeting
- As a general rule, all else being the same, *calibrating against a large data set* (in this case a large watershed such as Buttermilk Creek) *is more robust than calibrating against a smaller data set* (a smaller watershed such as Franks Creek)
- How can/will the *effects of this choice on model robustness* be evaluated by a sensitivity analysis?

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Ten-year time steps for the model runs are much too long unless many identical model runs are conducted

- Long global time steps are *not statistically equivalent to shorter steps* in their effect on the rainfall intensity-frequency (RIF) distribution
- Tucker's own guidance apparently contradicts his plan to use global time steps (Tg) as long as 10 years:

  "The model is relatively insensitive to Tg as long as its value is sufficiently small.... [Test r]esults showed that values of Tg of approximately 1 year or smaller produce very similar results... A value of 0.1 years was used in calibration and forward runs." (2010 EIS, Appendix F, page F-29)

- Note that *these are separate points!*

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Modeling runs are apparently using incorrect rainfall intensity-frequency (RIF) distributions

- It appears from my own calculations (using Excel and Fortran) that the RIFs used by Tucker, Price, and Doty for the CHILD modeling runs that supported the 2010 EIS are *wrong* (rainfall intensity *substantially low by any reasonable measure*)
- This apparent problem applies to all of the 2010-era CHILD model runs, including the "wet scenario" runs
- It apparently applies to *current* modeling runs as well
- Tucker and I need to compare RIF calculations
- If my RIF calculations are correct, *this raises a serious question about whether those who have been doing the erosion modeling for the West Valley site during the past decade are qualified to continue this work*

Modeling runs are apparently using incorrect rainfall intensity-frequency (RIF) distributions

- It appears from my own calculations (using Excel and Fortran) that the RIFs used by Tucker, Price, and Doty for the CHILD modeling runs that supported the 2010 EIS are *wrong* (rainfall intensity *substantially low*)
- Tucker uses 0.15 inch mean depth of rainfall during storms (or 0.3 inch for "wet scenario"), and multiplies this value by the negative natural log of a random number to generate individual storm rainfall depths
- Tucker uses 2.57 hr mean duration of storms and multiplies this value by the negative natural log of a random number for individual storm durations
- Tucker uses 0.08 as the fraction of time during which storms occur

Modeling runs are apparently using incorrect rainfall intensity-frequency (RIF) distributions

EIS (2010) 24-hr rainfall*	EIS (2010) "wet" 24-hr rainfall**	USDA 24-hr rainfall***	Return interval
0.9 inches	1.9 inches	2.1 inches	1 year
1.0 inches	2.1 inches	2.5 inches	2 years
1.2 inches	2.3 inches	3.2 inches	5 years
1.3 inches	2.5 inches	3.7 inches	10 years
1.4 inches	2.8 inches	4.4 inches	25 years
1.5 inches	3.0 inches	4.7 inches	50 years
1.6 inches	3.2 inches	5.2 inches	100 years

*24-hr rainfall calculated by R. Vaughan from 2010 EIS stochastic input values (0.15 inch mean storm depth, 2.57 hr mean storm duration, 0.08 storm fraction)
**24-hr rainfall calculated by R. Vaughan from 2010 EIS "wet scenario" values (0.30 inch mean storm depth, 2.57 hr mean storm duration, 0.08 storm fraction)
***24-hr design storms developed by USDA for various return intervals, from 2008 DEIS, Appx. F, p. F-22

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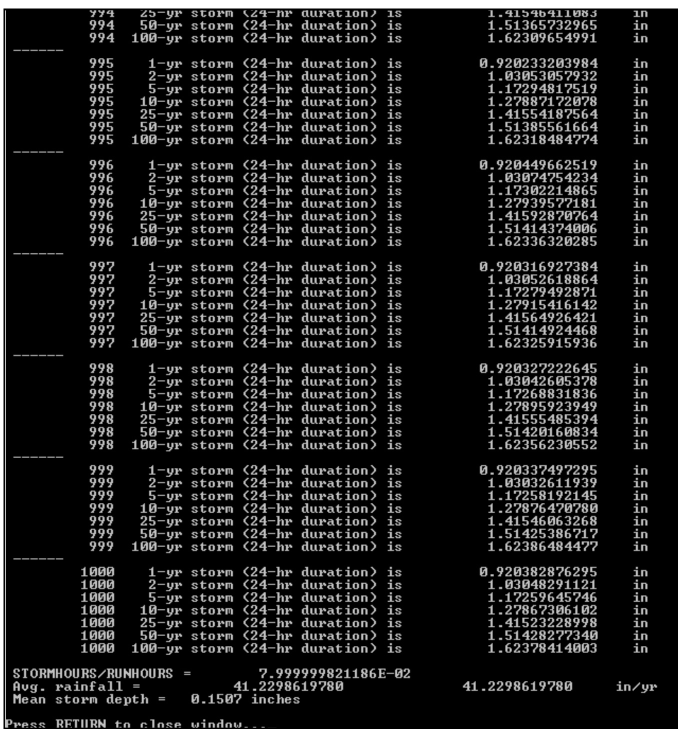
```
    994   25-yr storm (24-hr duration) is        1.41546411083    in
    994   50-yr storm (24-hr duration) is        1.51365732965    in
    994  100-yr storm (24-hr duration) is        1.62309654991    in
------
    995    1-yr storm (24-hr duration) is       0.920233203984    in
    995    2-yr storm (24-hr duration) is        1.03053057932    in
    995    5-yr storm (24-hr duration) is        1.17294817519    in
    995   10-yr storm (24-hr duration) is        1.27887172078    in
    995   25-yr storm (24-hr duration) is        1.41554187564    in
    995   50-yr storm (24-hr duration) is        1.51385561664    in
    995  100-yr storm (24-hr duration) is        1.62318484774    in
------
    996    1-yr storm (24-hr duration) is       0.920449662519    in
    996    2-yr storm (24-hr duration) is        1.03074754234    in
    996    5-yr storm (24-hr duration) is        1.17302214865    in
    996   10-yr storm (24-hr duration) is        1.27939577181    in
    996   25-yr storm (24-hr duration) is        1.41592870764    in
    996   50-yr storm (24-hr duration) is        1.51414374006    in
    996  100-yr storm (24-hr duration) is        1.62336320285    in
------
    997    1-yr storm (24-hr duration) is       0.920316927384    in
    997    2-yr storm (24-hr duration) is        1.03052618864    in
    997    5-yr storm (24-hr duration) is        1.17279492871    in
    997   10-yr storm (24-hr duration) is        1.27915416142    in
    997   25-yr storm (24-hr duration) is        1.41564926421    in
    997   50-yr storm (24-hr duration) is        1.51414924468    in
    997  100-yr storm (24-hr duration) is        1.62325915936    in
------
    998    1-yr storm (24-hr duration) is       0.920327222645    in
    998    2-yr storm (24-hr duration) is        1.03042605378    in
    998    5-yr storm (24-hr duration) is        1.17268831836    in
    998   10-yr storm (24-hr duration) is        1.27895923949    in
    998   25-yr storm (24-hr duration) is        1.41555485394    in
    998   50-yr storm (24-hr duration) is        1.51420160834    in
    998  100-yr storm (24-hr duration) is        1.62356230552    in
------
    999    1-yr storm (24-hr duration) is       0.920337497295    in
    999    2-yr storm (24-hr duration) is        1.03032611939    in
    999    5-yr storm (24-hr duration) is        1.17258192145    in
    999   10-yr storm (24-hr duration) is        1.27876470780    in
    999   25-yr storm (24-hr duration) is        1.41546063268    in
    999   50-yr storm (24-hr duration) is        1.51425386717    in
    999  100-yr storm (24-hr duration) is        1.62386484477    in
------
   1000    1-yr storm (24-hr duration) is       0.920382876295    in
   1000    2-yr storm (24-hr duration) is        1.03048291121    in
   1000    5-yr storm (24-hr duration) is        1.17259645746    in
   1000   10-yr storm (24-hr duration) is        1.27867306102    in
   1000   25-yr storm (24-hr duration) is        1.41523228998    in
   1000   50-yr storm (24-hr duration) is        1.51428277340    in
   1000  100-yr storm (24-hr duration) is        1.62378414003    in

STORMHOURS/RUNHOURS =      7.99999821186E-02
Avg. rainfall =          41.2298619780             41.2298619780    in/yr
Mean storm depth =   0.1507 inches

Press RETURN to close window...
```

Output from my Fortran program which takes about a minute to run 1000 iterations of one hundred years' worth of stochastic storms (the 1000 iterations are averaged).

I've also set up an Excel spreadsheet for the same purpose.

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…The Wet scenario predicts the greatest depth and extent and incision in the Franks Creek–Erdman Brook confluence area, with net incision depths along the northeast and northwest sides of the SDA/NDA on the order of 10 to 20 meters (32.81 to 65.62 feet) and locally reaching approximately 25 meters (82.02 feet). Other scenarios, however, show stability of the valley network in the Franks Creek–Erdman Brook confluence area, with some reaches undergoing net deposition and others net incision, all generally less than 10 meters (32.81 feet). Thus, scenarios A2, A3, and Wet are the most consistent with present-day stream incision/deposition patterns.

F.3.1.6.11 Discussion of Forward Modeling Results
There are three general categories of potential outcome that might arise from a study like this. First, one might find that under virtually all sets of scenarios and assumptions, the burial areas are prone to rapid erosional exhumation. Alternatively, one might find that nearly all scenarios point toward long-term future stability against erosion. Finally, one might obtain a more ambiguous result in which some scenarios show a significant erosional threat, and others do not. The results from this study contain elements of both the second and third outcomes. None of the scenarios showed large-scale erosional exhumation of the Main Plant Process Building, NDA, or SDA. However, the Wet scenario and its variations suggest a potential for exposure under certain conditions.

2010 EIS, Appendix F, p. F-77

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…Apart from gully incision along the NDA–SDA boundary, all scenarios produced relatively little erosion on the South Plateau. The relative lack of computed erosion on the South Plateau may seem surprising, but it appears to be a robust outcome of the modeling. The absence of significant gully erosion along the SDA rim in the simulations, even under the Wet scenario, reflects the restricted surface drainage area available to feed gullies. All of the scenarios, to varying degrees, point toward continued incision of the North Plateau by gullies growing inward from the rim. Not surprisingly, the most extreme gully incision occurs under the Wet sitewide close-in-place scenario. In this scenario, the North Plateau is heavily dissected by several very large gullies extending from the north and west (Figure F–30). While none of these breach the proposed containment mound over the Main Plant Process Building, two of them come close: the tip of the western gully approaches within about 80 meters (262.46 feet) of the high-level radioactive waste tanks, while the tip of the northern gully comes within about 120 meters (393.70 feet).

How realistic is the Wet scenario? Its likelihood as a future-climate scenario is very difficult to quantify, simply because a great deal of uncertainty surrounds future-climate projections (particularly concerning rainfall). Yet one can ask first how representative it may be of modern conditions. The fact that this scenario is consistent with observed erosion around the Franks Creek–Erdman Brook confluence (more so than some of the other cases) suggests that it may be a closer representation of onsite conditions than the unrealistically high rainfall intensity might suggest.

2010 EIS, Appendix F, p. F-78

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Modeling runs are apparently using incorrect rainfall intensity-frequency (RIF) distributions

- **Possible response from Tucker: "The major determinant of the erosion rate was the large number of high-frequency storms (i.e., 2- and 10-year events), not the few low-frequency storms (i.e., 100-year and probable maximum precipitation events). This conclusion is consistent with other research findings reported in the literature (Wolman and Miller 1960)."** **(Quoted from 2010 EIS, Appendix F, page F-84)**
- **My response: *Let's do it right* and see what that shows!**
- **Also: Higher storm intensity correlates w/higher stream velocity, which is more erosive (kinetic energy = $\frac{1}{2}mV^2$) and which favors *erosion and sediment entrainment (net removal)* rather than settling (net deposition)**

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Questions?

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```
program test
!
!  Program to calculate RIF distribution used for WV CHILD runs that supported 2010 EIS
!
!  Ray Vaughan 6/24/17
!
implicit none

integer              :: STORMNUMBER,ITERATION
double precision   :: RUNHOURS,RUNDAYS,RUNYEARS,STORMPROPORTION
double precision   :: STORMRAININCHES, STORMDURATIONHOURS,X
double precision   :: MEANSTORMRAININCHES, MEANSTORMDURATIONHOURS
double precision   :: MAXINCHES1YR,MAXINCHES2YR,MAXINCHES5YR
double precision   :: MAXINCHES10YR,MAXINCHES25YR,MAXINCHES50YR,MAXINCHES100YR
double precision   :: MAXINCHES1YRSUM,MAXINCHES2YRSUM,MAXINCHES5YRSUM
double precision   :: MAXINCHES10YRSUM,MAXINCHES25YRSUM,MAXINCHES50YRSUM,MAXINCHES100YRSUM
double precision   :: DAY1INCHES,DAY2INCHES,DAY3INCHES,STORMHOURS
double precision   :: RAINTOTALINCHES1,RAINTOTALINCHES2,ERROR

!
! Assumed values (i.e., values used for CHILD runs for 2010 EIS)
!
MEANSTORMRAININCHES = 0.15
MEANSTORMDURATIONHOURS = 2.57
STORMPROPORTION = 0.08
!
! FORTRAN program..........................
!
MAXINCHES1YRSUM = 0.0
MAXINCHES2YRSUM = 0.0
MAXINCHES5YRSUM = 0.0
MAXINCHES10YRSUM = 0.0
MAXINCHES25YRSUM = 0.0
MAXINCHES50YRSUM = 0.0
MAXINCHES100YRSUM = 0.0
!
ITERATION = 0
 DO
  ITERATION = ITERATION + 1
  !
  call RANDOM_SEED
  !
  RUNHOURS = 0.0
  STORMHOURS = 0.0
  !
  RAINTOTALINCHES1 = 0.0
  RAINTOTALINCHES2 = 0.0
```

```
  !
  MAXINCHES1YR = 0.0
  MAXINCHES2YR = 0.0
  MAXINCHES5YR = 0.0
  MAXINCHES10YR = 0.0
  MAXINCHES25YR = 0.0
  MAXINCHES50YR = 0.0
  MAXINCHES100YR = 0.0
  !
  STORMNUMBER = 0
   DO
    STORMNUMBER = STORMNUMBER + 1
    !
    call RANDOM_NUMBER(X)
    STORMRAININCHES = MEANSTORMRAININCHES * (-LOG(X))
    RAINTOTALINCHES1 = RAINTOTALINCHES1 + STORMRAININCHES
    !
    call RANDOM_NUMBER(X)
    STORMDURATIONHOURS = MEANSTORMDURATIONHOURS * (-LOG(X))
    STORMHOURS = STORMHOURS + STORMDURATIONHOURS
    !
    IF(STORMDURATIONHOURS.LE.24.0) DAY1INCHES = STORMRAININCHES
    IF(STORMDURATIONHOURS.LE.24.0) DAY2INCHES = 0.0
    IF(STORMDURATIONHOURS.LE.24.0) DAY3INCHES = 0.0
    !
    IF(STORMDURATIONHOURS.GT.24.0.AND.STORMDURATIONHOURS.LE.48.0) DAY1INCHES = STORMRAININCHES * 24.0/STORMDURATIONHOURS
    IF(STORMDURATIONHOURS.GT.24.0.AND.STORMDURATIONHOURS.LE.48.0) DAY2INCHES = STORMRAININCHES - DAY1INCHES
    IF(STORMDURATIONHOURS.GT.24.0.AND.STORMDURATIONHOURS.LE.48.0) DAY3INCHES = 0.0
    !
    IF(STORMDURATIONHOURS.GT.48.0.AND.STORMDURATIONHOURS.LE.72.0) DAY1INCHES = STORMRAININCHES * 24.0/STORMDURATIONHOURS
    IF(STORMDURATIONHOURS.GT.48.0.AND.STORMDURATIONHOURS.LE.72.0) DAY2INCHES = DAY1INCHES
    IF(STORMDURATIONHOURS.GT.48.0.AND.STORMDURATIONHOURS.LE.72.0) DAY3INCHES = STORMRAININCHES - DAY1INCHES - DAY2INCHES
    !
    RAINTOTALINCHES2 = RAINTOTALINCHES2 + DAY1INCHES + DAY2INCHES + DAY3INCHES
    ERROR = ABS(RAINTOTALINCHES1 - RAINTOTALINCHES2)
    IF(ERROR.GE.1E-10) print*, "RAINTOTALINCHES1 not  equal to RAINTOTALINCHES2 at STORMNUMBER ", STORMNUMBER
    IF(ERROR.GE.1E-10) print*, "  Error is ", ERROR, " inches"
    IF(ERROR.GE.1E-10) stop
    !
    RUNHOURS = RUNHOURS + STORMDURATIONHOURS/STORMPROPORTION
    RUNDAYS = RUNHOURS/24.0
    RUNYEARS = RUNDAYS/365.25
    !
    IF(RUNYEARS.LE.1.0.AND.DAY1INCHES.GT.MAXINCHES1YR) MAXINCHES1YR = DAY1INCHES
    IF(RUNYEARS.LE.2.0.AND.DAY1INCHES.GT.MAXINCHES2YR) MAXINCHES2YR = DAY1INCHES
    IF(RUNYEARS.LE.5.0.AND.DAY1INCHES.GT.MAXINCHES5YR) MAXINCHES5YR = DAY1INCHES
    IF(RUNYEARS.LE.10.0.AND.DAY1INCHES.GT.MAXINCHES10YR) MAXINCHES10YR = DAY1INCHES
```

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```
    IF(RUNYEARS.LE.25.0.AND.DAY1INCHES.GT.MAXINCHES25YR) MAXINCHES25YR = DAY1INCHES
    IF(RUNYEARS.LE.50.0.AND.DAY1INCHES.GT.MAXINCHES50YR) MAXINCHES50YR = DAY1INCHES
    IF(RUNYEARS.LE.100.0.AND.DAY1INCHES.GT.MAXINCHES100YR) MAXINCHES100YR = DAY1INCHES
    !
    ! print*, ITERATION, STORMNUMBER, RUNYEARS, " years"
    IF(STORMNUMBER.EQ.20000) print*, "------"
    !
    IF(RUNYEARS.GE.100.0) EXIT
  END DO
  !
  MAXINCHES1YRSUM = MAXINCHES1YRSUM + MAXINCHES1YR
  MAXINCHES2YRSUM = MAXINCHES2YRSUM + MAXINCHES2YR
  MAXINCHES5YRSUM = MAXINCHES5YRSUM + MAXINCHES5YR
  MAXINCHES10YRSUM = MAXINCHES10YRSUM + MAXINCHES10YR
  MAXINCHES25YRSUM = MAXINCHES25YRSUM + MAXINCHES25YR
  MAXINCHES50YRSUM = MAXINCHES50YRSUM + MAXINCHES50YR
  MAXINCHES100YRSUM = MAXINCHES100YRSUM + MAXINCHES100YR
  !
  print*, ITERATION, "    1-yr storm (24-hr duration) is", MAXINCHES1YRSUM/ITERATION, "in"
  print*, ITERATION, "    2-yr storm (24-hr duration) is", MAXINCHES2YRSUM/ITERATION, "in"
  print*, ITERATION, "    5-yr storm (24-hr duration) is", MAXINCHES5YRSUM/ITERATION, "in"
  print*, ITERATION, "   10-yr storm (24-hr duration) is", MAXINCHES10YRSUM/ITERATION, "in"
  print*, ITERATION, "   25-yr storm (24-hr duration) is", MAXINCHES25YRSUM/ITERATION, "in"
  print*, ITERATION, "   50-yr storm (24-hr duration) is", MAXINCHES50YRSUM/ITERATION, "in"
  print*, ITERATION, "  100-yr storm (24-hr duration) is", MAXINCHES100YRSUM/ITERATION, "in"
  !
  IF(ITERATION.GE.1000) EXIT
END DO
!
print*, " "
print*, "STORMHOURS/RUNHOURS = ", STORMHOURS/RUNHOURS
print*, "Avg. rainfall = ", RAINTOTALINCHES1/RUNYEARS, RAINTOTALINCHES2/RUNYEARS, " in/yr"
print "(a,f8.4,a)", " Mean storm depth = ", RAINTOTALINCHES1/REAL(STORMNUMBER), " inches"
!
stop
end
```

(Fortran FTN95)

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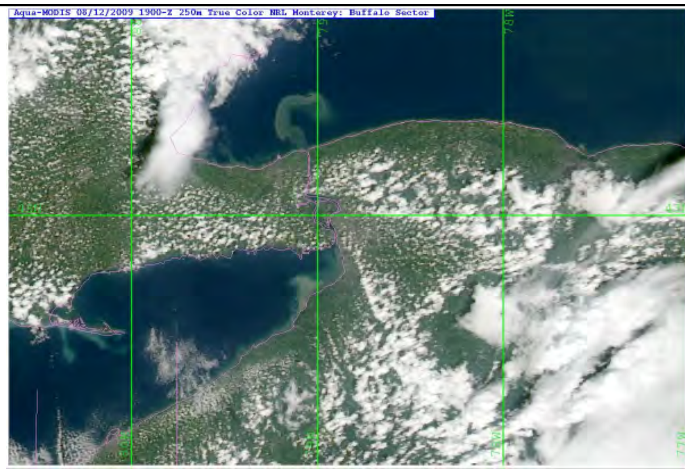
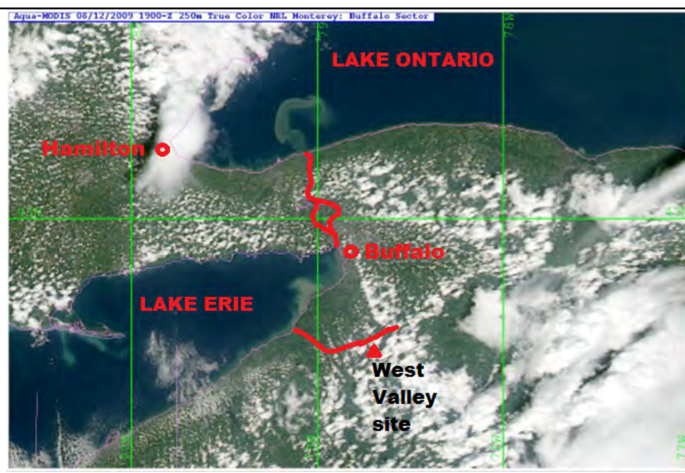


The sediment plume from the August 2009 storm went into Lake Erie, then mostly followed the south shore to Buffalo, then flowed through the Niagara River into Lake Ontario

Plume is a good tracer or surrogate for past (see Joshi) & future plumes of radioactive contamination from the site



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