



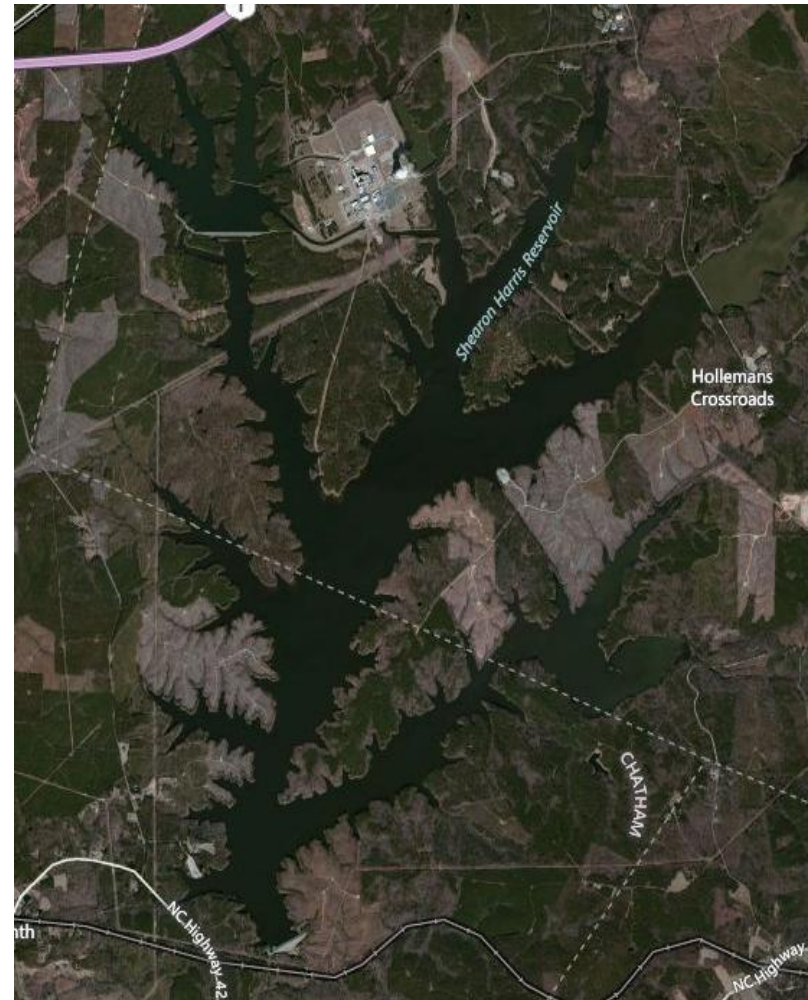
The Dose Impact from the Evaporation of Harris Lake

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Harris Nuclear Plant

- Harris Nuclear Plant is a single unit PWR in New Hill, NC
- The plant is located in the middle of a ~11,000 acre site– 4,200 acres (6.5 miles²) of which is occupied by Harris Lake.
- Cooling is provided by a Cooling Tower and all releases are discharged to the lake via the Cooling Tower Blowdown Line.



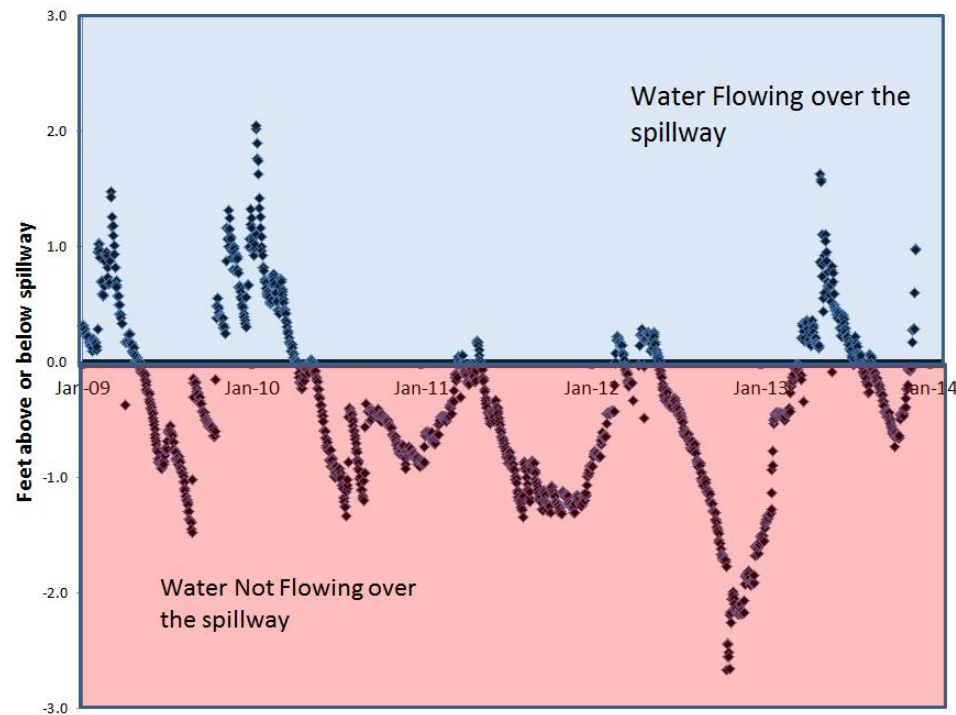
Harris Lake

- Man-made reservoir with an average depth of 15 feet and is surrounded by woods
- Permitted release point for all plant discharges (radioactive, NPDES, Cooling, etc)
- The lake is fed by a couple of minor creeks and surface runoff.
- The main dam will allow water to overflow via the spillway into Buckhorn Creek
- The lake only flows over the spillway when there is sufficient rain (typically spring months)



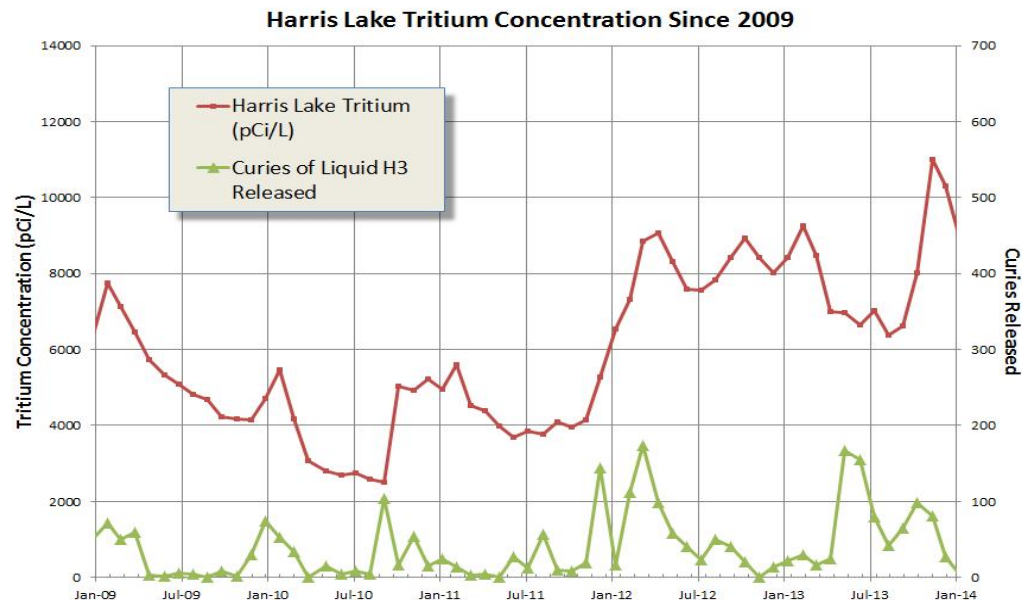
Lake Level

- The level of Harris Lake strongly depends upon rainfall.
- When the lake elevation is higher than the spillway, tritium is removed by “lake blowdown”
- From 2009 to 2014, the lake “blowdown” about 25% of the time. The average lake elevation was about ½ foot below the spillway



Tritium Concentration

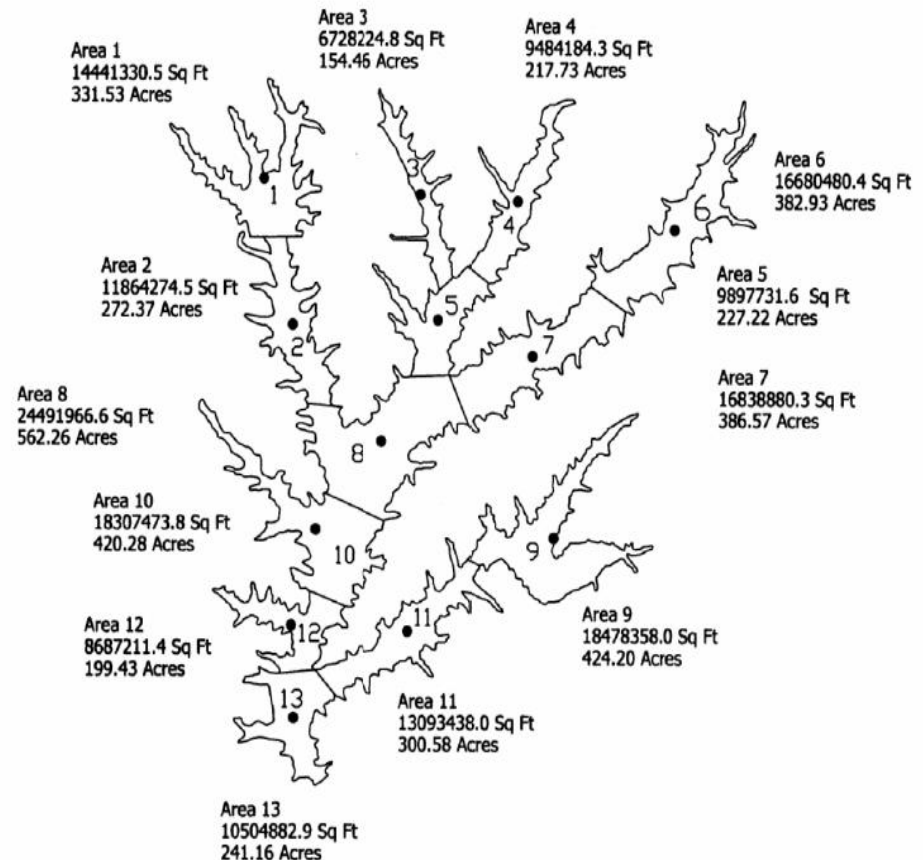
- Harris Lake tritium concentration depends upon the concentration of tritium in a release tank, lake elevation, and rainfall.
- In general, a liquid release tank with 1 uCi/ml of tritium will increase the tritium concentration of the lake about 1000 pCi/L
- From 2009 to 2014 lake tritium concentration ranged from 2,500 – 11,000 pCi/L (2013 average = 8,010 pCi/L)



- Radioactive tank discharges are permitted for liquid release and use the ingestion pathways of fish consumption and drinking water
 - In 2013 HNP released 806 Ci of tritium and 50 mCi of Fission & Activation products (mostly Co-58) via the liquid pathway
 - $\text{Dose}_{\text{liquid}} = 2.86\text{E-}02$ mrem/yr Total Body
 - $\text{Dose}_{\text{liquid}} = 5.67\text{E-}02$ mrem/yr, GI-LLI (max organ)
- The evaporation from the surface of Harris Lake potentially creates a new gaseous dose pathway from a liquid release which is >10% of the total dose from all pathways

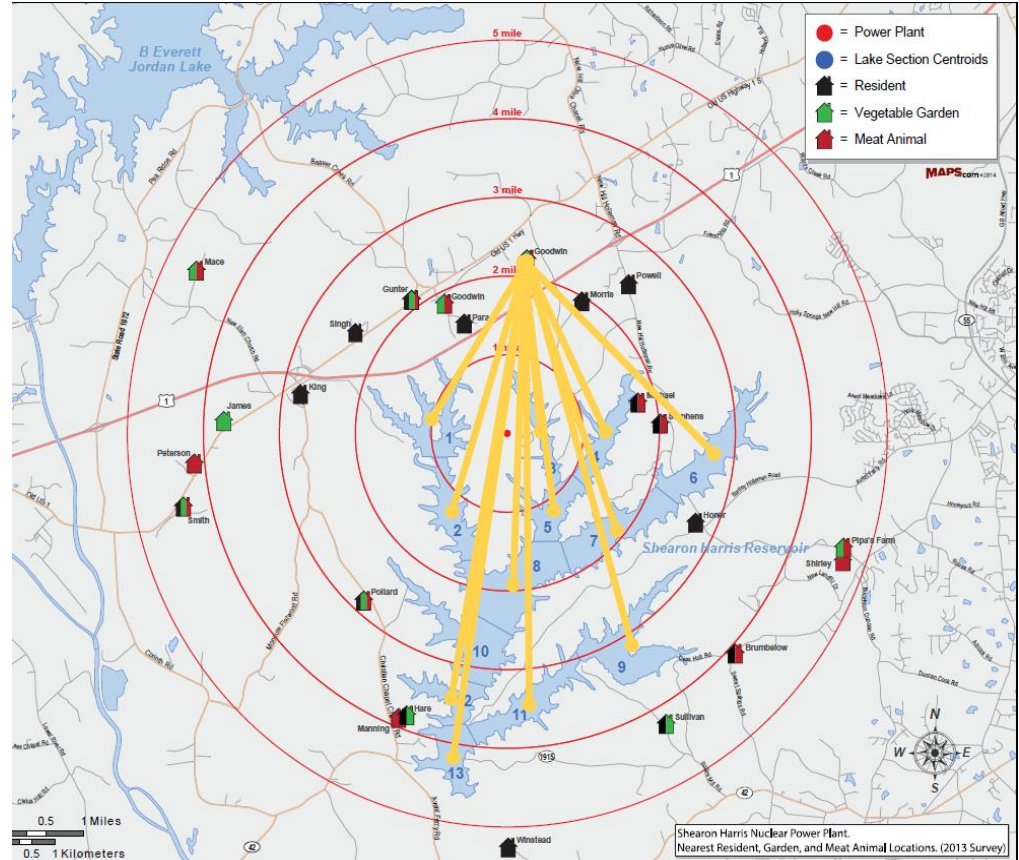
Division of Harris Lake

- Due to the uneven shape and large surface area, Harris Lake was divided into 13 sections
- Area and center point of each sector was determined using Auto-CAD.
- This was done to determine the impact of each lake section on each receptor point



Land Use Census

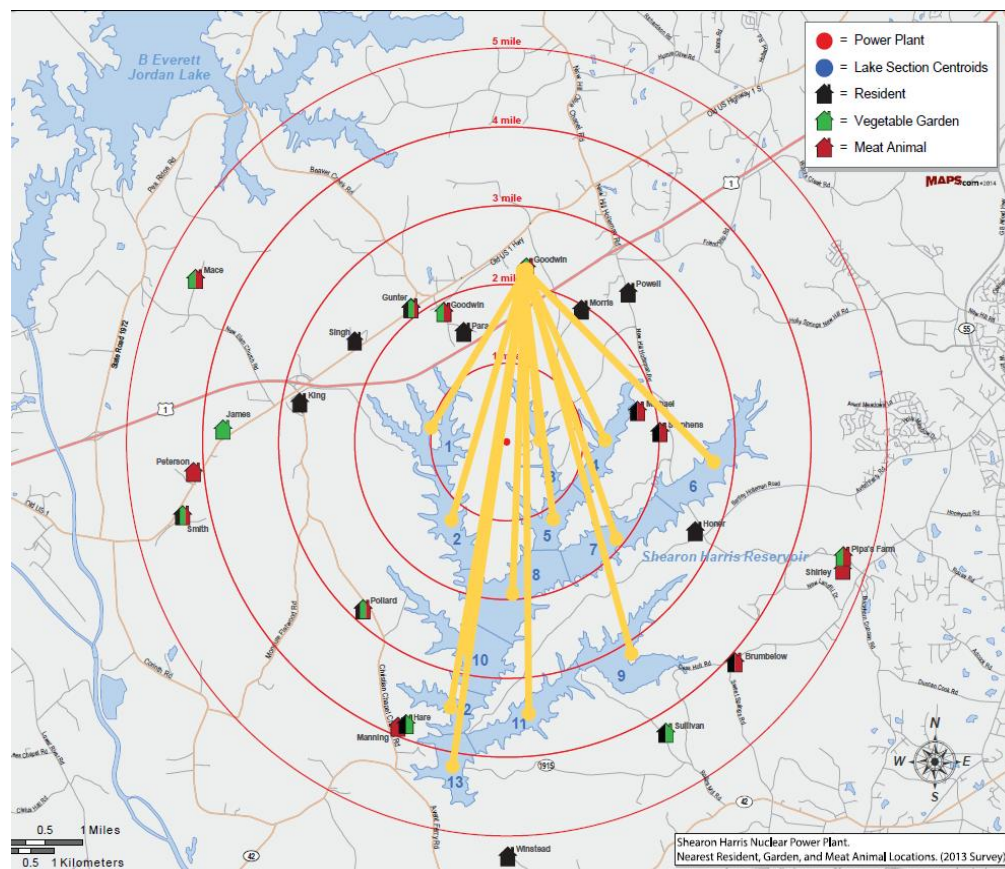
- 2013 Land Use Census identified 16 nearest resident locations, 10 nearest garden locations, and 12 nearest meat animal locations. (no milk)
- The distance and direction from each lake sector centroid to each resident location was determined
- X/Q were calculated using NRC XOQDOQ program for Ground Level Release (performed by Hirsh Shah, Murray & Trettel)



Goodwin Location

		meters	miles	X/Q
1	NNE	3899	2.42	1.03E-06
2	NNE	5361	3.33	6.45E-07
3	N	3473	2.16	9.15E-07
4	NNW	4021	2.5	6.24E-07
5	N	5179	3.22	5.00E-07
6	NW	5544	3.44	5.42E-07
7	NNW	5971	3.71	3.49E-07
8	N	6702	4.16	3.47E-07
9	NNW	8164	5.07	2.23E-07
10	N	7859	4.88	2.77E-07
11	N	9139	5.68	2.23E-07
12	N	9321	5.79	2.18E-07
13	N	10357	6.43	1.88E-07

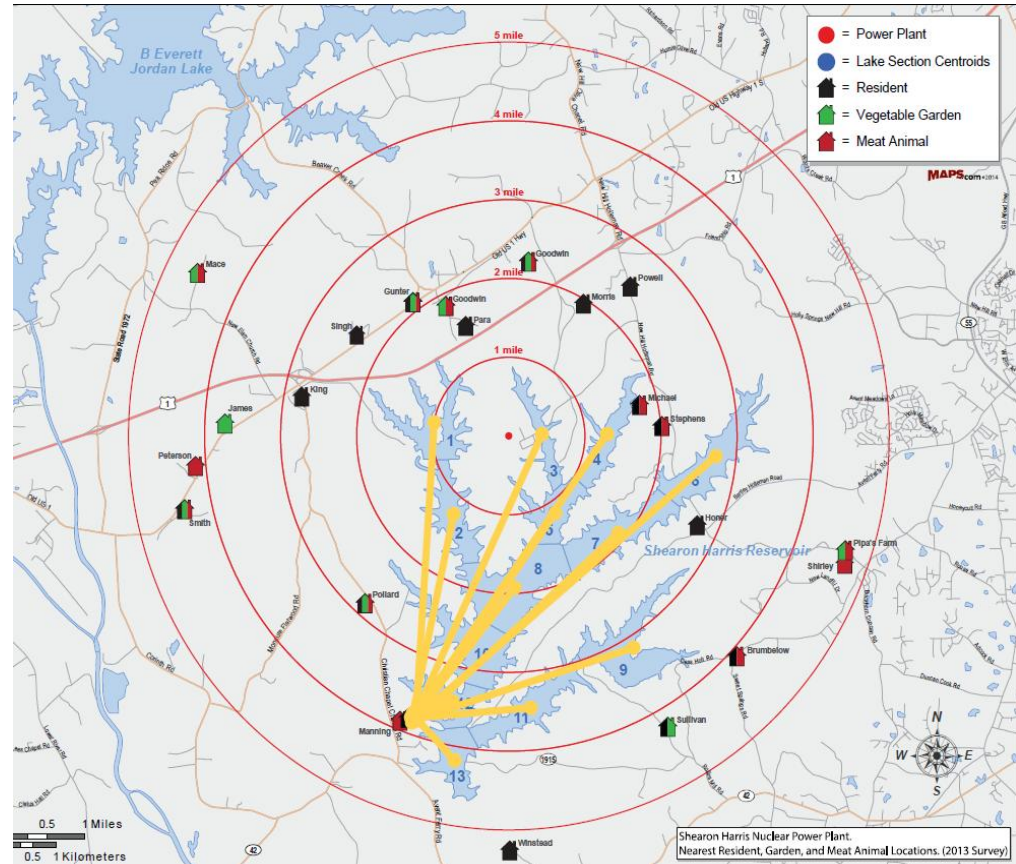
- This calculation was repeated for each 16 resident locations (208 unique X/Q were determined)



Hare Location

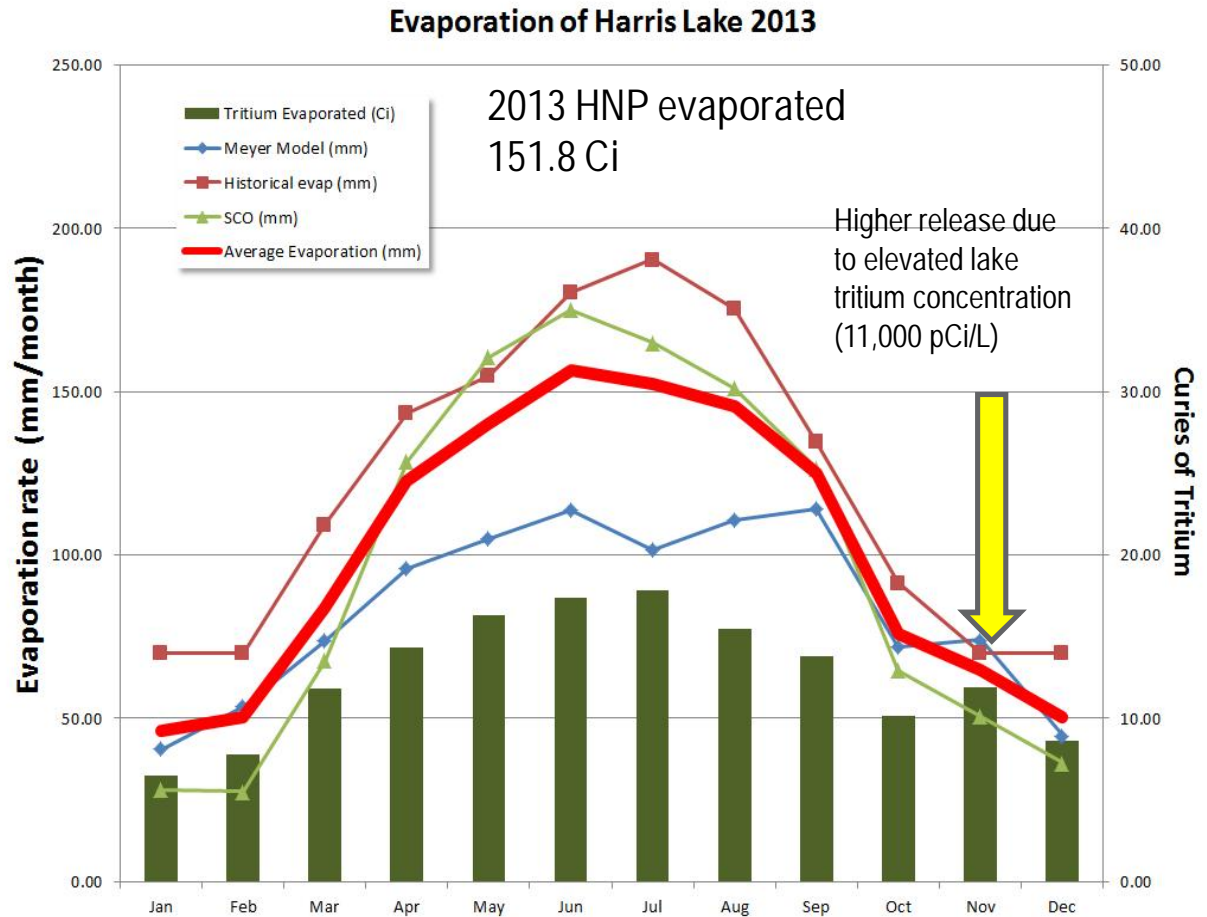
		meters	miles	X/Q
1	S	5849	3.63	1.45E-06
2	SSW	4204	2.61	2.37E-06
3	SSW	6336	3.94	1.33E-06
4	SW	7006	4.35	1.57E-06
5	SW	5179	3.22	2.35E-06
6	SW	8408	5.22	1.23E-06
7	SW	5849	3.63	2.00E-06
8	SW	9626	5.98	1.02E-06
9	WSW	4935	3.07	1.44E-06
10	SW	1950	1.21	9.86E-06
11	W	2681	1.67	1.49E-06
12	W	1097	0.68	6.32E-06
13	NW	1401	0.87	4.34E-06

- This calculation was repeated for each 16 resident locations (208 unique X/Q were determined)



Evaporation Rate of Harris Lake

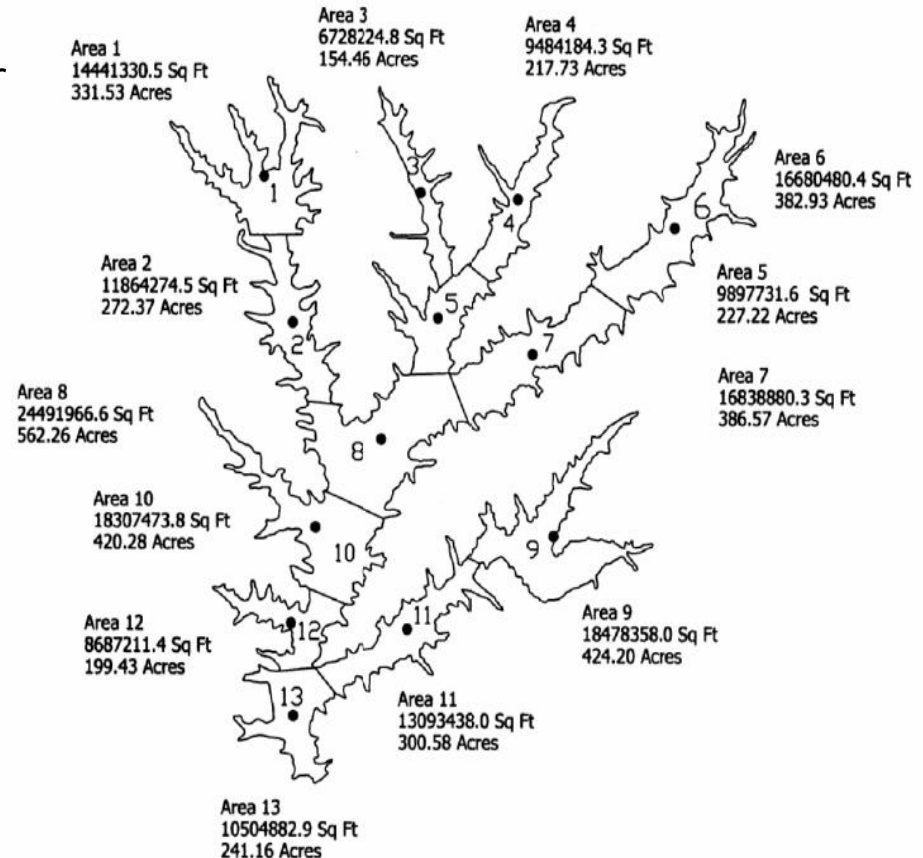
- 3 methods are used to calculate the monthly evaporation of the lake
 - Meteorological Model (Meyer model) based upon actual humidity, lake temperature, and wind velocity at height 25 feet above the lake
 - Average rate based on historical data for Chapel Hill, NC
 - Evaporation Rates published by the State Climate Office for Raleigh, NC



Division of Harris Lake

- The sample point is located at the spillway and is a monthly composite sample
- the Curies of Tritium evaporated for each of the 13 sectors = average evaporation rate × sector's surface area × the monthly composite Lake tritium concentration
- Assume the tritium is uniformly distributed through the lake

Jan 2013	Acres	Curies
1	331.53	0.52
2	272.37	0.43
3	154.46	0.24
4	217.73	0.34
5	227.22	0.36
6	382.93	0.60
7	386.57	0.61
8	562.26	0.88
9	424.20	0.67
10	420.28	0.66
11	300.58	0.47
12	199.43	0.31
13	241.16	0.38



Tritium Concentration at Goodwin Location

		meters	miles	X/Q
1	NNE	3899	2.42	1.03E-06
2	NNE	5361	3.33	6.45E-07
3	N	3473	2.16	9.15E-07
4	NNW	4021	2.5	6.24E-07
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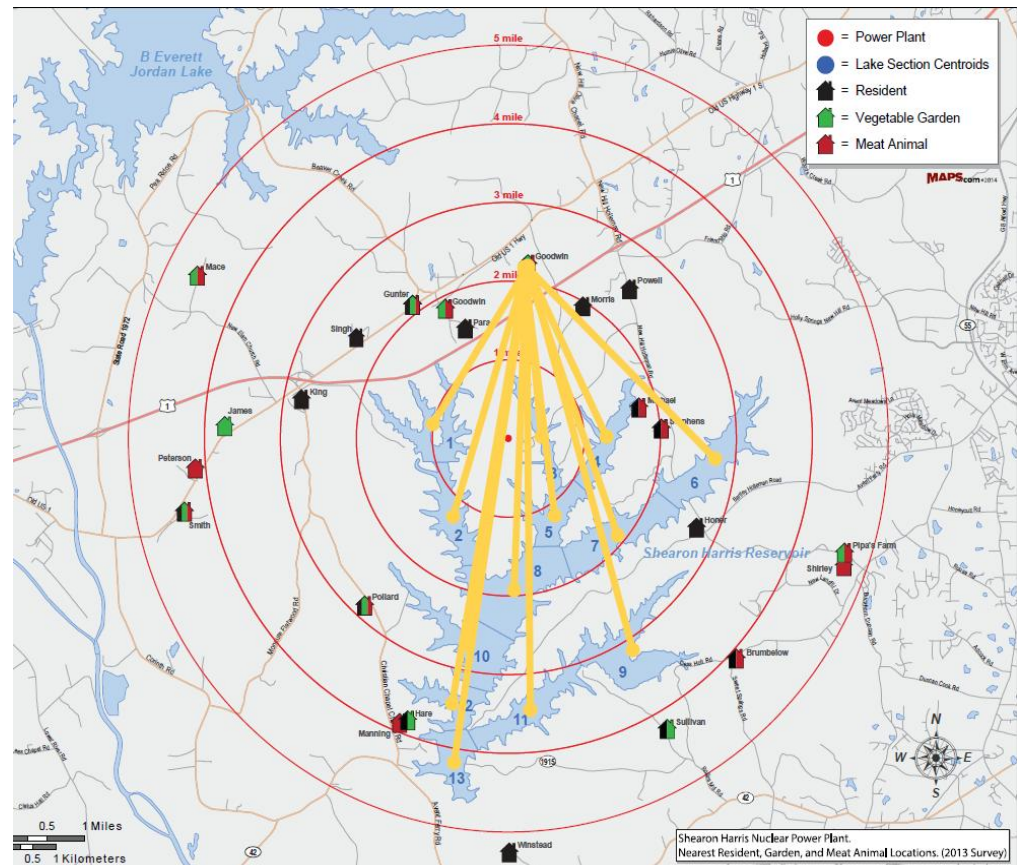
From Section 1 center to Goodwin

$$X/Q = 1.03E-06 \text{ sec/m}^3$$

Jan 2013 0.52 Curies (0.52E+12 pCi) of tritium evaporated from Section 1

There are 31 days (2.68E+06 sec) in January

This calculation assumes that only tritium evaporates from Harris Lake, no other isotopes are involved



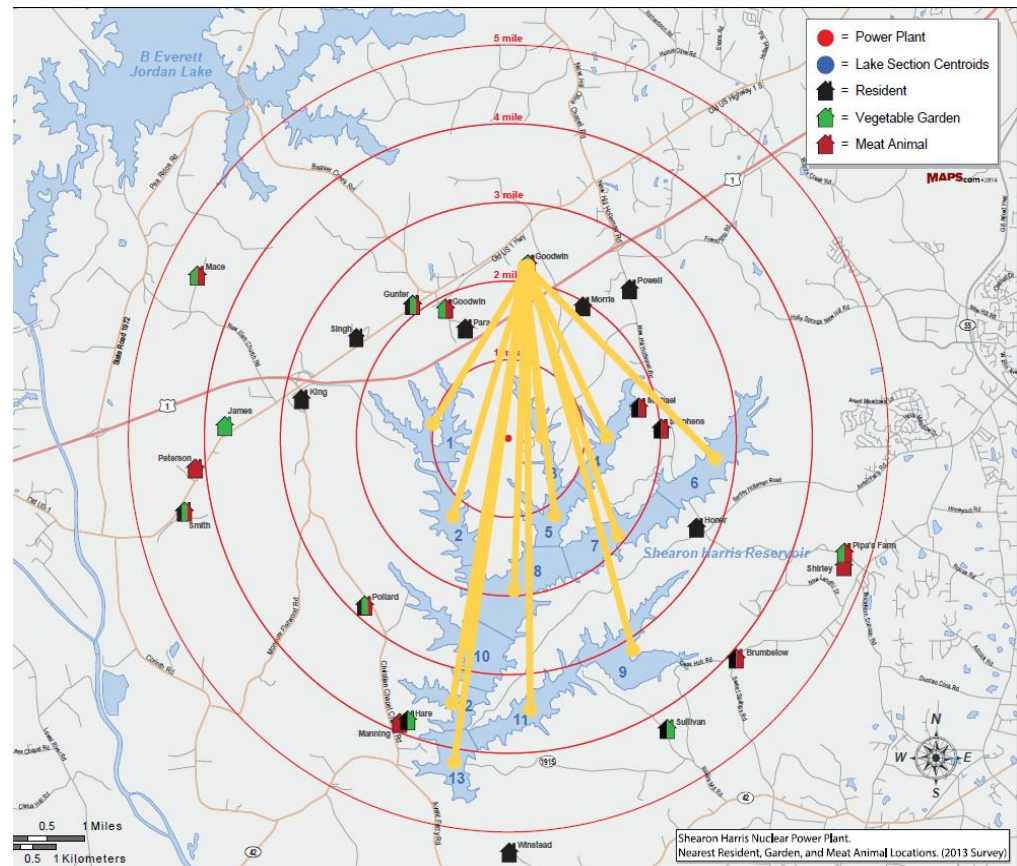
Tritium concentration in January 2013 from Section 1

$$\frac{0.52E+12 \text{ pCi} * 1.03E-06 \text{ sec/m}^3}{2.68E+06 \text{ sec}} = 0.20 \text{ pCi/m}^3$$

$$2.68E+06 \text{ sec}$$

Tritium Concentration at Goodwin Location

Section	miles	X/Q	Jan (Ci)	Tritium (pCi/m ³)
1	2.42	1.03E-06	0.52	0.200
2	3.33	6.45E-07	0.43	0.104
3	2.16	9.15E-07	0.24	0.082
4	2.5	6.24E-07	0.34	0.079
5	3.22	5.00E-07	0.36	0.067
6	3.44	5.42E-07	0.6	0.121
7	3.71	3.49E-07	0.61	0.079
8	4.16	3.47E-07	0.88	0.114
9	5.07	2.23E-07	0.67	0.056
10	4.88	2.77E-07	0.66	0.068
11	5.68	2.23E-07	0.47	0.039
12	5.79	2.18E-07	0.31	0.025
13	6.43	1.88E-07	0.38	0.027
Total January 2013				1.062

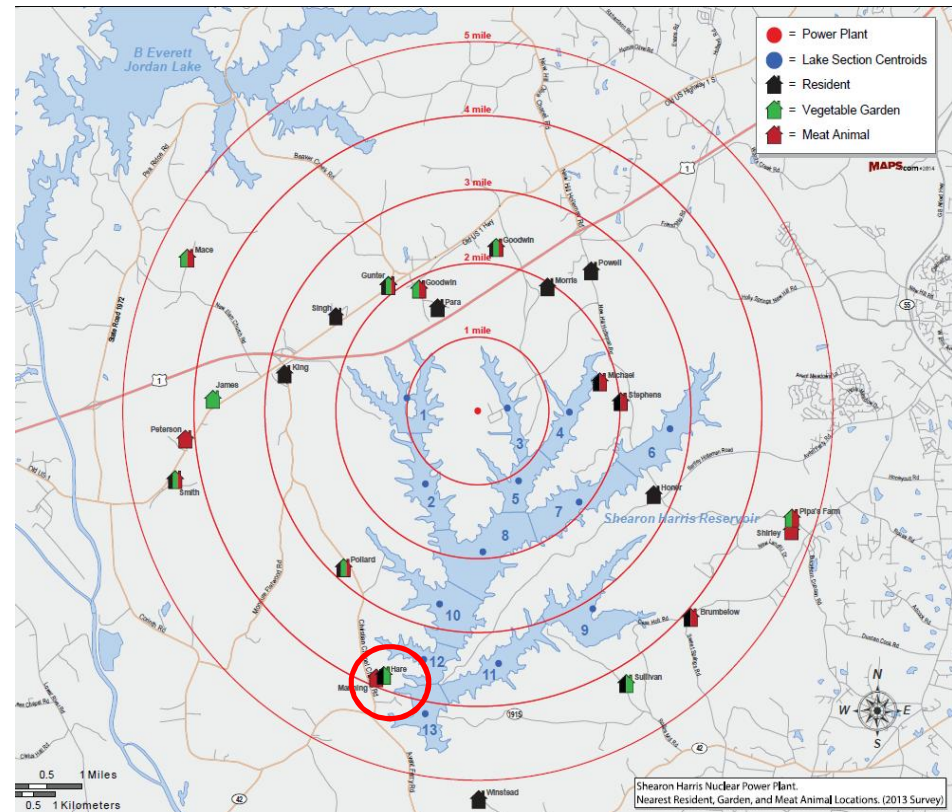


For January 2013, the average tritium concentration in the air at Goodwin location was 1.062 pCi/m³

This calculation is repeated for each month and each location (THANK YOU HIRSH!!!!!!)

Tritium Dose

- The quarterly dose for each location was calculated based upon the land use census receptors (THANKS HIRSH!!!)
 - Goodwin Location – resident, garden, meat pathway (no milk pathway)
- In 2013 child living in the SSW sector 3.8 miles away from the plant received the highest dose = $1.23E-01$ mrem/yr (total body & organ)
 - Inhalation = $2.92E-02$ mrem/yr
 - Garden = $9.29E-02$ mrem/yr
 - Meat = $7.52E-03$ mrem/yr



Annual Liquid Dose for 2013

		1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Annual Total
Total Body	Liquid Releases (mrem)	1.04E-03	8.37E-03	8.14E-03	1.10E-02	2.86E-02
	Harris Lake Evaporation (mrem)	2.11E-02	3.95E-02	3.84E-02	2.50E-02	1.23E-01
	Total Body (mrem)	2.23E-02	4.79E-02	4.65E-02	3.60E-02	1.53E-01
	10CFR50 Appendix I Limit (mrem)	1.50 E+00	1.50 E+00	1.50 E+00	1.50 E+00	3.00 E+00
Organ	Liquid Releases (mrem)	2.69E-03	9.03E-03	1.56E-02	2.94E-02	5.67E-02
	Harris Lake Evaporation (mrem)	2.11E-02	3.95E-02	3.84E-02	2.50E-02	1.23E-01
	Total Critical Organ (mrem)	2.38E-02	4.85E-02	5.40E-02	3.44E-02	1.80 E-01
	10CFR50 Appendix I Limit (mrem)	5.00 E+00	5.00 E+00	5.00 E+00	5.00 E+00	1.00 E+01

- The liquid release dose is based upon drinking water and fish consumption for a release and includes all isotopes (including H3 and HTD)
- The Harris Lake evaporation dose is based upon inhalation, garden, and meat pathway

Annual Dose

- The annual doses from the Harris Lake evaporation is added to the liquid release doses because the evaporation creates a gaseous pathway from a liquid release.
 - The dose from the evaporation of Harris Lake is >10% than the dose from the liquid release and needs to be included in the annual dose assessment.
- Despite the additional exposure pathway, the liquid release doses are well within regulatory limits
 - Annual Total Body dose $1.53\text{E-}01$ mrem (5.1% of 3 mrem limit)
 - Organ dose (GI-LLI) $1.80\text{E-}01$ mrem (1.8% of 10 mrem limit)

Summary

- The evaporation of Harris Lake causes a gaseous pathway exposure from a liquid release.
- The lake was divided into 13 sections and the concentration from the evaporated tritium for each resident location was calculated based
- The dose from the evaporation of the lake is added to the liquid release dose and compared to liquid release limits
- The 2013 annual total body and organ dose from the evaporation of Harris Lake was $1.23\text{E}-01$ mrem to a child in the SSW section 3.8 miles from the site.
- This resulted in a $1.53\text{E}-01$ mrem/y total body dose from the liquid pathway

Take Away

- Impact of natural evaporation needs to be considered at a nuclear power plant
- Evaporation from a reservoir or a lake generates dose via gaseous pathway from liquid release
- Tritium release due to evaporation from a reservoir can be several hundred curies annually
- Tritium dose to nearby residents can be larger than dose from other plant sources
- Impact of a very large body of water can be estimated by dividing it into several sections

