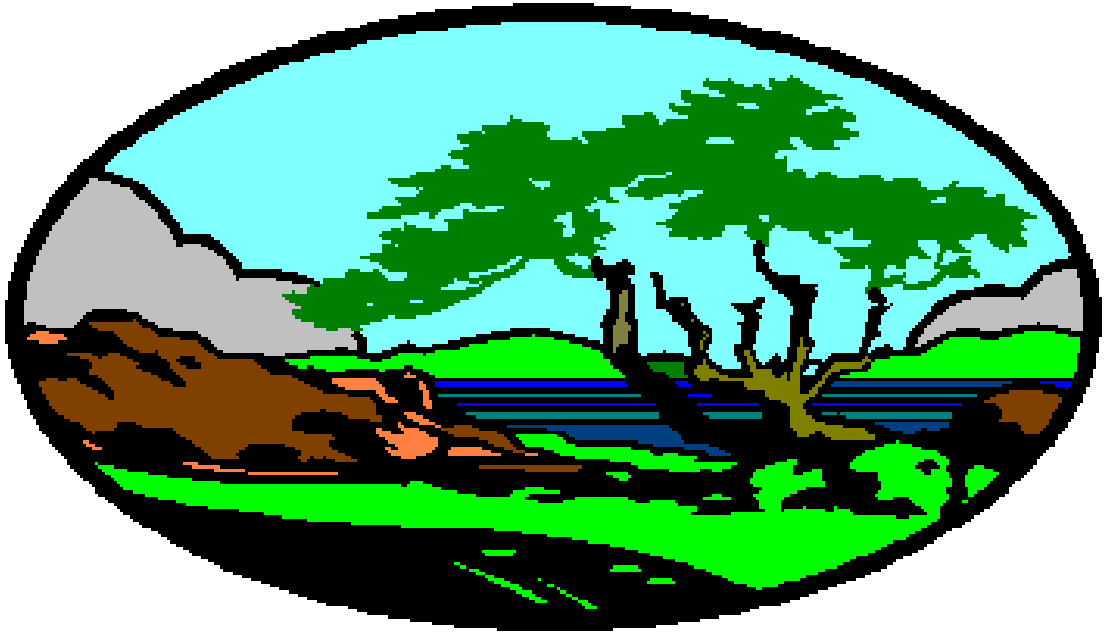
Outside the ODCM Box

Case Studies



Jim Key – Key Solutions, Inc.

Presented at the 2013 RETS-REMP Workshop

Westminister, CO / July 24-27, 2013

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What Happens if

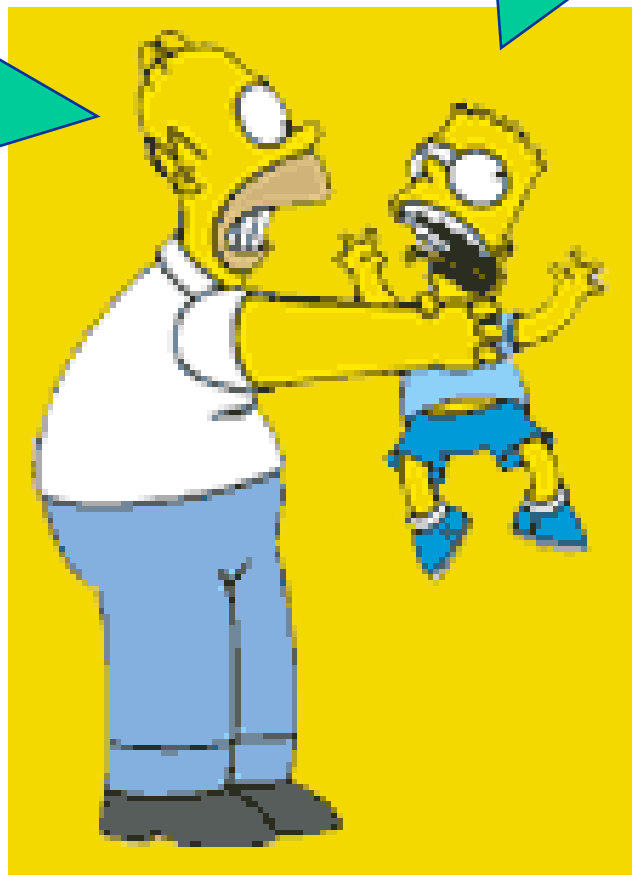
We blew a tank of liquid radwaste out the stack last night! *

What's the Dose Impact?

Tell Me The Dose!!!

GIVE ME THAT STINKING DOSE OR I'LL ….

It's NOT in the ODCM!!!



* True event. Operation is stranger than fiction.

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What You Have to Show

- Compliance With NRC Offsite Concentration Limits
  - Liquids: 10 × ECL of Part 20
  - Gaseous: Dose Rate Limits
- Compliance With NRC App I Dose Limits
- Compliance with EPA
  - 40 CFR 141 and 40 CFR 190
- Compliance with EPA is "*demonstrated*" by compliance with NRC – App I.

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What You Must Know

- As a Minimum
  - Nuclide Source Term
    - Direct Measurement - Very Important
    - Other Ways to Estimate Source Term.
  - Release Duration
    - Start / Stop
  - Release Rate
    - Average and Max Release Rates
  - Release Volume

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Additional Information

- Meteorology During Release
- Plant Conditions
- How did it leave the site?
  - Liquid
    - Through non-effluent discharge pathway?
    - Atmospheric Recapture?
  - Airborne
    - Evaporation?
    - Resuspension?

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More Information

- May need additional information beyond what land use census provides.
- Any non-routine pathways of exposure?
  - Reg Guide 1.109 and NUREG 0133 have very limited number of exposure pathways.

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Outside of ODCM Space

- Document what you can.
  - Source Term
  - Volume and Rate of Release
- For 1st pass use maximizing assumptions for information that is unavailable or questionable.
- Determine pathways of exposure.
  - Are there potential dose exposure mechanisms that are not found in 1.109 or 0133.

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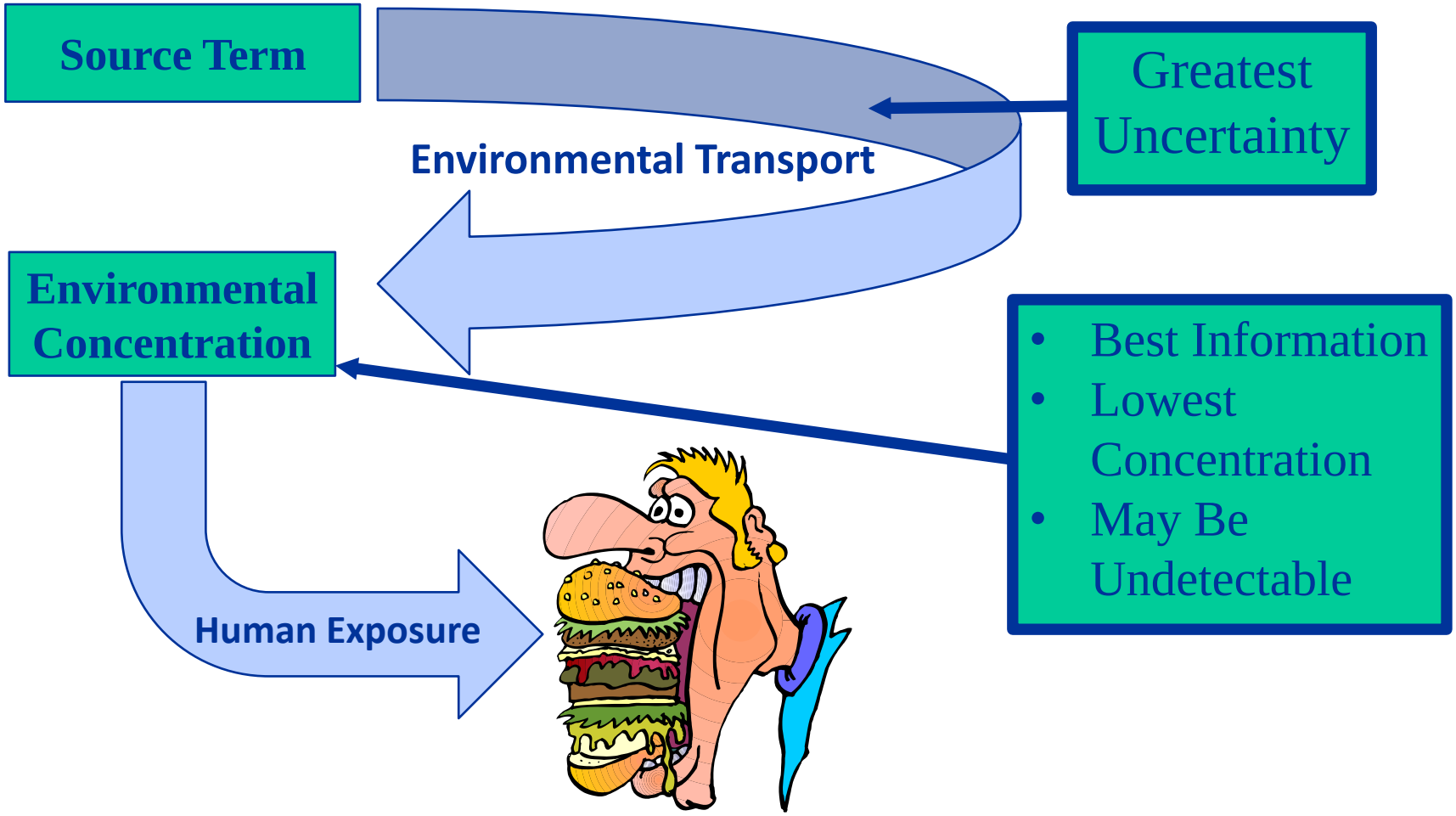
Where to Sample?



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Concentration Limits

- Instantaneous Limits
  - "the second is used as the practical reporting time unit for established release rates" [NUREG 0133]
- In effect at location of highest offsite concentration.
  - Liquids – Site Boundary
  - Gases – Usually Site Boundary (not necessarily so for BWRs)
- No credit for dilution or decay in the environment.

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Dose Limits

- Three Sets of Limits
  - Liquid
  - Noble Gas
  - Radioiodine, Tritium and Particulates (RTP)
- Annual and Quarterly Limits
  - Must be determined in accordance with the methodology and parameters in the ODCM
  - Doses to be determined every 30 days.

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Environmental Monitoring

- Radiological Environmental Monitoring Program (REMP)
  - Guidance found in Branch Technical Position (BTP) in NUREGs 1301 or 1302
  - Focuses on monitoring human exposure pathways.
- Does Not Address Compartments/Pathways in the Eco-System That May Provide Better Information on Environmental Impact

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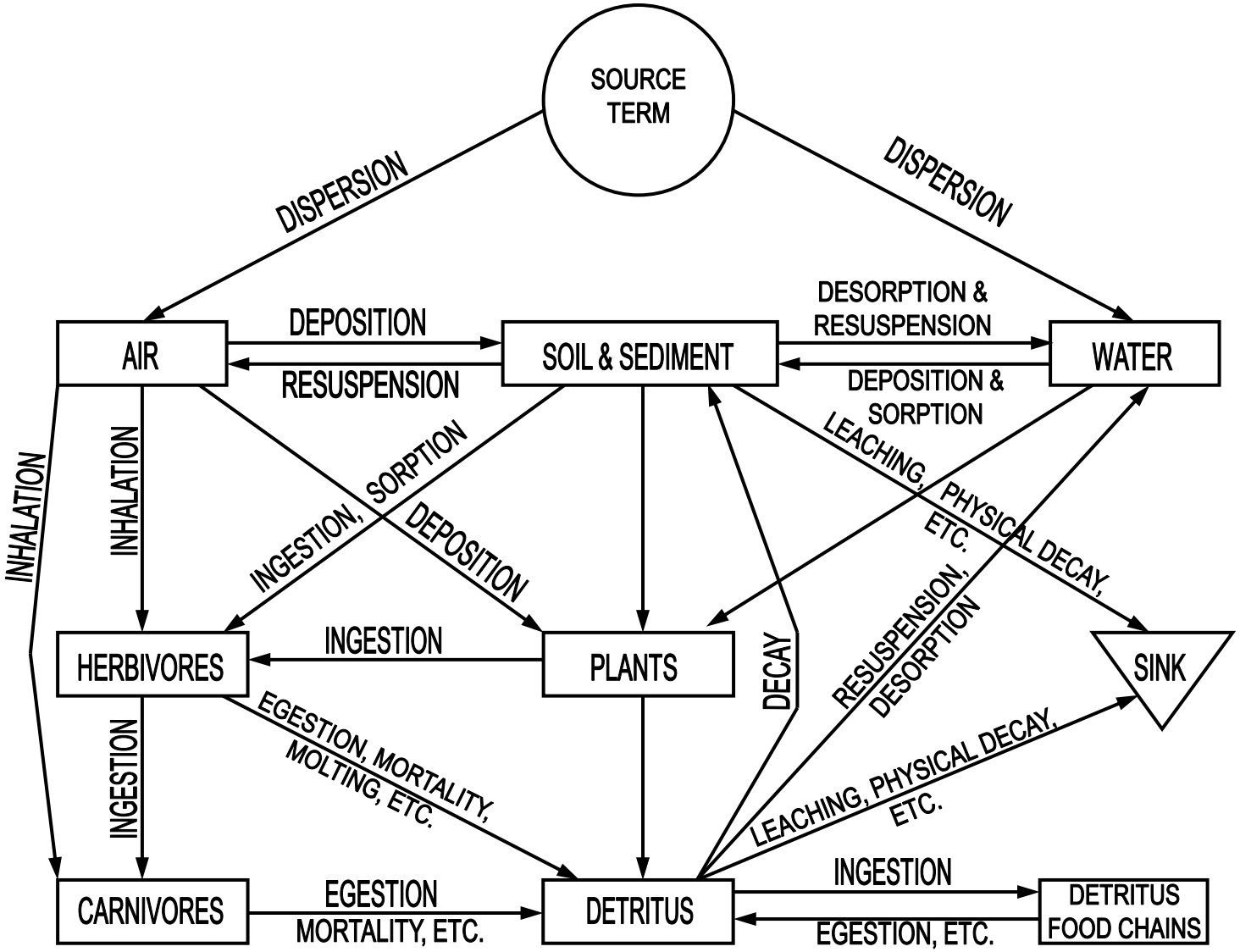
Principle Ecosystem Components



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Land Use Census

- From NUREG 0133:
  - "It is the intent … that a licensee undertake annual surveys of the age groups and the land use …"
- Purpose is to identify the age group, location, and exposure pathways that all combine to generate the highest dose potential.

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How Do We Comply?

- Environmental concentrations can be below what can be directly measured.
- Dose limits so low that dose cannot be determined directly.
- ODCM Provides Means of Compliance:
  - Measurements
  - Set Points
  - Calculations

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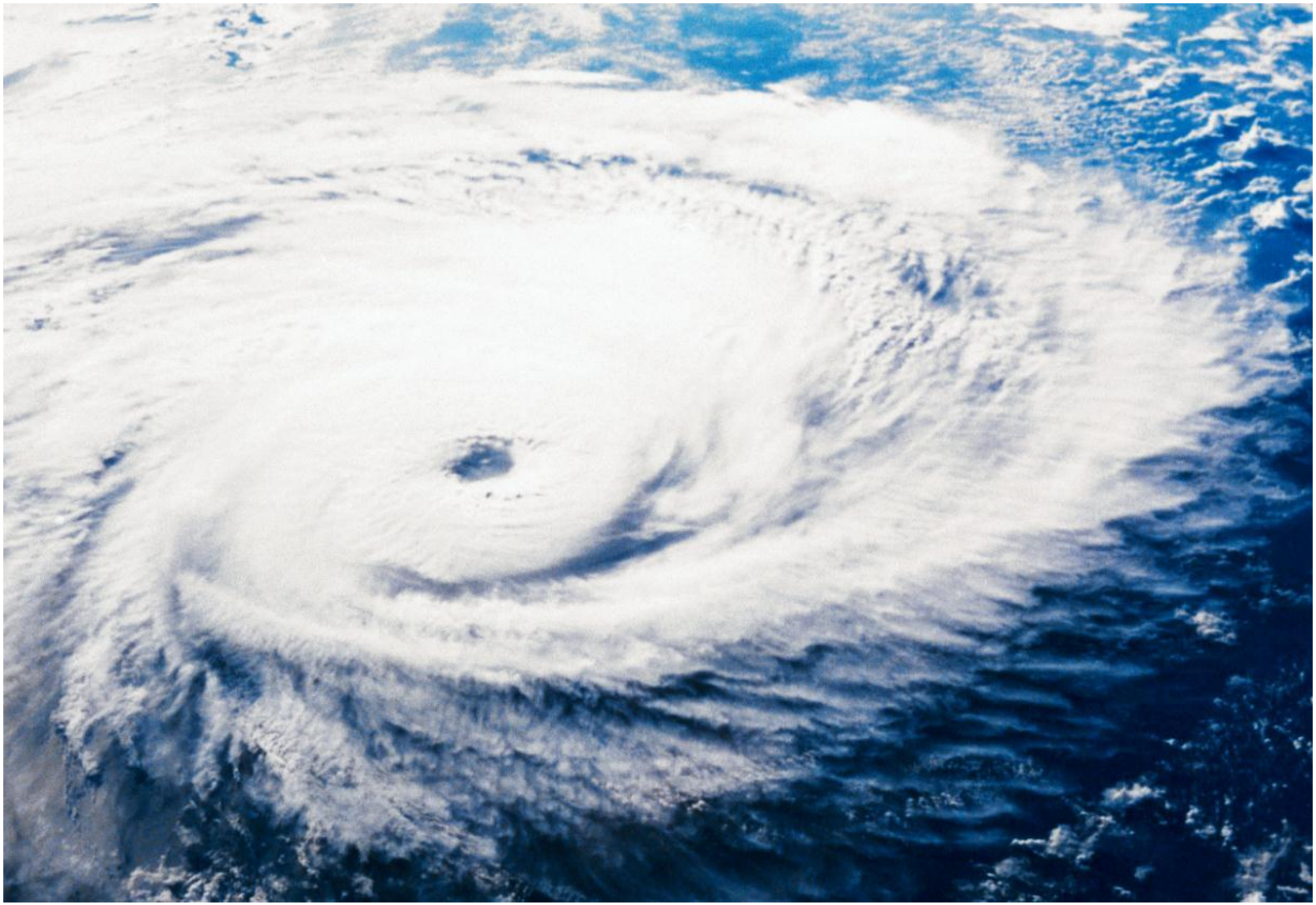
Hurricane!!



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Uncontrolled and Unmonitored Release

- **Prior to Event – Routine Air Sampling Had Shown Airborne Activity Inside Structure**
- **Damage to Structure Resulted in Atmospheric Release!**
- **Meteorology Lost as Winds Increased!!!!**
- **Was RTP and/or NG Dose Rate Exceeded (airborne concentration)?**
- **Was App I Dose Exceeded?**

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Simple – Talk to the Experts

- Years Ago Hurricane Resulted in Loss of Condensate Storage Tank at Ocean Site
  - Call those guys and see what they did!
  - “Are you crazy. We didn’t even try to do a dose assessment.”
  - “There’s no way to do those calcs…”

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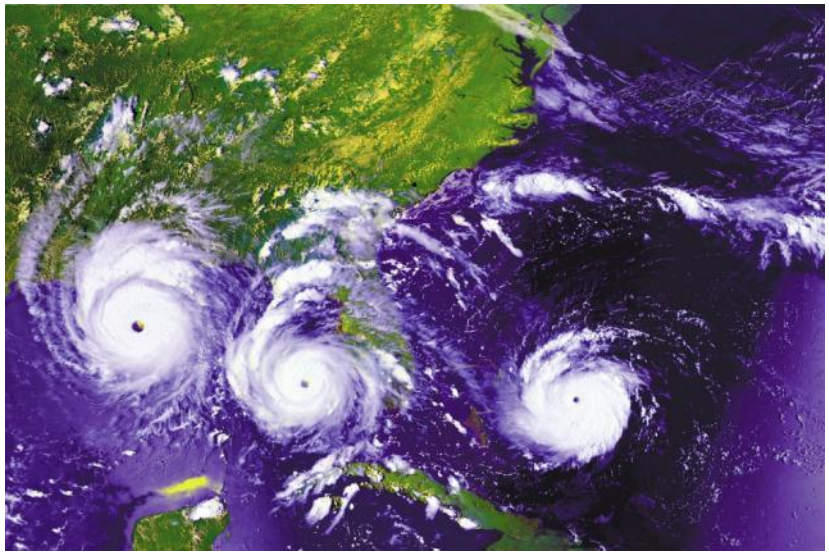
Call a Hurricane Expert!



- Spoke with chief meteorologist at National Hurricane Center”
  - “What did you say happened!?!?!?!”
  - “What are you trying to do?”
  - “Are you crazy – we don’t even try do those calculations.”

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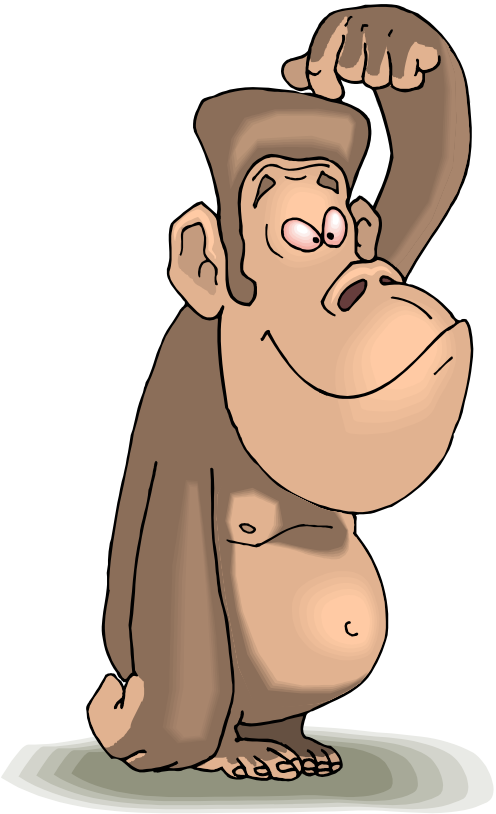
Input From Experts

- Two professional opinions on my sanity.



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So Look at the Questions Again

- Did you exceed the dose rate limits (e.g. airborne concentration limits)?
- Did you exceed the Appendix I limits?

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Dose Rate Depends On

- Source Term
  - Generated source term based on highest concentration for each nuclide as measured just prior to event.
- Rate of Release
  - Assumed instantaneous release.
- Dispersion
  - Assumed no atmospheric dispersion!
  - Set X/Q = 1

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Dose Rate Determination

- Extremely Conservative Assumptions
  - Use best available information.
    - Airborne Concentration Info
  - When unavailable use defendable but conservative assumptions.
    - Source Term Based on Maximum Observed Concentrations
    - X/Q is always less than 1. Even for extremely high values of X/Q.*

(* Note corollary: 1 ≠ 2 . Not even for extremely large values of 1.)

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Dose Rate Limits - III

- Why Use Ridiculous Value of 1 for X/Q?
  - The dose rate limits are *instantaneous* limits.
    - Act to limit *maximum instantaneous air concentration*.
    - NUREG 0133: Reporting time unit is the *second*.
  - The limits are applicable at *or beyond* the site boundary at the location of max dose rate.
  - The dose rate limits apply *whether or not* member of public is actually present.
- Result – Dose Rates *Were Not Exceeded*

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Appendix I Dose

- Dose to a Member of the Public Depends On:
  - Source Term
  - Total Activity Released
  - Location of Receptor
  - Dose Exposure Pathways.

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Appendix I Dose - II

- Total Activity Released:
  - Max Concentration (uCi/cc) x Volume of Turbine Building (cc)
- Dispersion (X/Q)
  - Used Worst Case (conservative) Site Boundary X/Q (annual average)

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Appendix I Dose - III

- Dispersion (X/Q)
  - X/Q is Inversely Proportional to Wind Speed
    - Wind speed goes up – X/Q goes down.
    - High wind speeds (hurricane) means annual average X/Q is conservative
  - X/Q is Proportional to Atmospheric Stability
    - Atmospheric instability increases – X/Q goes down
    - Unstable atmospheric conditions (hurricane) means average X/Q is conservative
- Result – App I Dose Limits *Were Not* Exceeded

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The Problem- Sassafras Albidum

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- Sassafras Tree Leaves Were Collected by REMP Vendor and Analyzed
- Results Came Back Positive for Cs-137
- Additional Samples Were Taken
  - Leaves Still Positive
  - Twigs Sampled Showed Higher Levels Than Leaves

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Lots of Samples

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Soil Samples

- Taken close to tree
  - Some Positive
  - Some Negative
- Nothing seen in soil samples taken at distance from tree.

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Clues

- Leaves Can Integrate Activity Over Time
  - Purpose of sampling leafy vegetation is to determine seasonal deposition rather than long term environmental buildup.
  - Cesium has a long residence time in the environment under certain conditions.
- Twig Samples Substantially Higher Than Leaves
  - Cesium can concentration in woody parts but not to the degree seen here.

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Time To Go On A Field Trip

- Examine Location Relative to Facility
- Examine General Setting
- Examine Tree
- Examine Sample Locations
- Examine the Ground

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Location Relative to Facility

- Tree located just beyond site boundary
- If result of recent site release would expect to see Cs all over the place.

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General Setting

One of These Trees In Not Like the Others
Can You Tell Which One?

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The Lone Sassafras Tree

- Only Deciduous Tree in a Small Forest of Conifers
  - Deciduous Tree Drops Foliage Every Year
  - Conifers Retain Foliage
- Tree Still Small in Size
  - Young
  - No Cs Found In Older Conifers

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Sample Locations at Base of Tree

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Clues

- Soil
  - Definite Distinction Between Soil Layers
  - ~ 2 Inch Layer of Detritus Out to Tree Drip Line
  - Sand Underneath With Little Organic Content
- Looked For and Found Large Clump of Lichen
  - Excellent capture and retention of Cs
    - High levels have been seen in reindeer milk and meat from bomb tests and Chernobyl.
  - No Cs seen on lichen.

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Very High Organic Content At Surface

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Approximately 2-3 Inches of Detritus

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Just Beneath The Detritus Layer

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Tree Was Recycling Cesium!

- Cs is soluble
  - In sandy soil rain will cause Cs to quickly migrate down into the soil.
  - Very effective continuous removal mechanism
- Organic matter and clay act as a sink for Cs
  - Detritus acted as long term sink for Cs
  - Cs is a nutrient analog for Potassium
  - K is essential nutrient for life processes
- Cs slowly leaching from detritus was quickly taken up by tree root system.
  - Over time concentrations can theoretically reach high levels.

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What About the Twigs?

- Substantially higher Cs concentration in twigs is reason for suspicion.
- Additional twigs sampled – still high.
- Vendor used chopper (blender) to process twigs for analysis.
- Blender was contaminated!

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Take Away

- Ideally should sample:
  - Annuals
  - Herbaceous Perennials
- Should not have sampled tree leaves!!!
- If sampling slow growing plants must understand how that will impact your results.
- Need to be aware of how the local environment will impact REMP samples.

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Storm Drain Tritium Discharges

Jim Key – Key Solutions, Inc.

© KSI - 2013

The Issue

- Discovery of Measurable H-3 Levels in Yard Storm Drains
- Not Routine Release Pathway
- NRC IE Bulletin 80-10 Requires Evaluation To Be Performed

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The Problem

- UFSAR Assumed All Liq Rad Waste Releases via Radwaste Line Into River
- Release To Environment Did Not Take Place Though Normal Effluent Discharge Pathway
- Became Necessary to Develop Pathway Specific Dilution Factors

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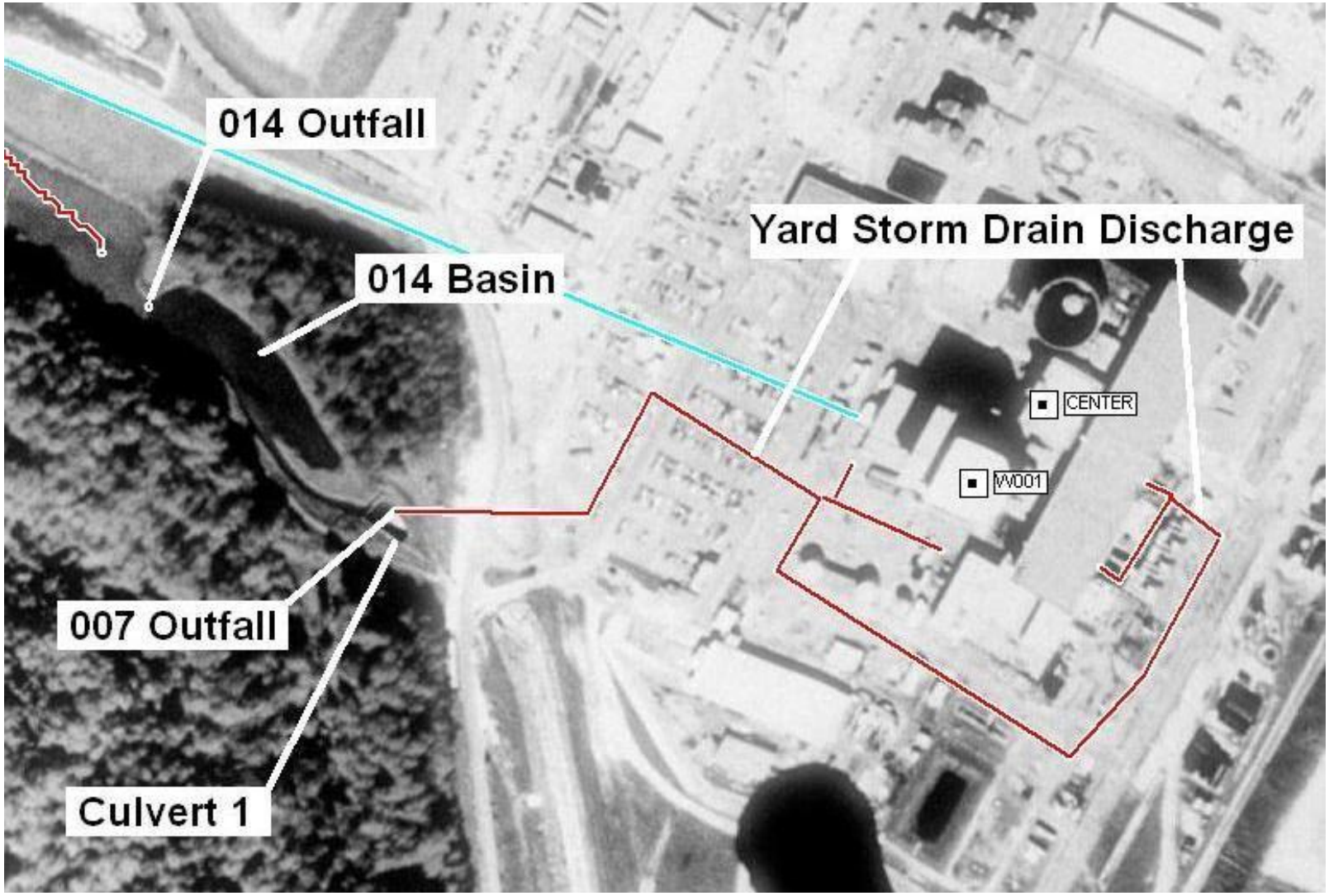
Yard Drain Release Pathway



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Yard Drain to Culvert

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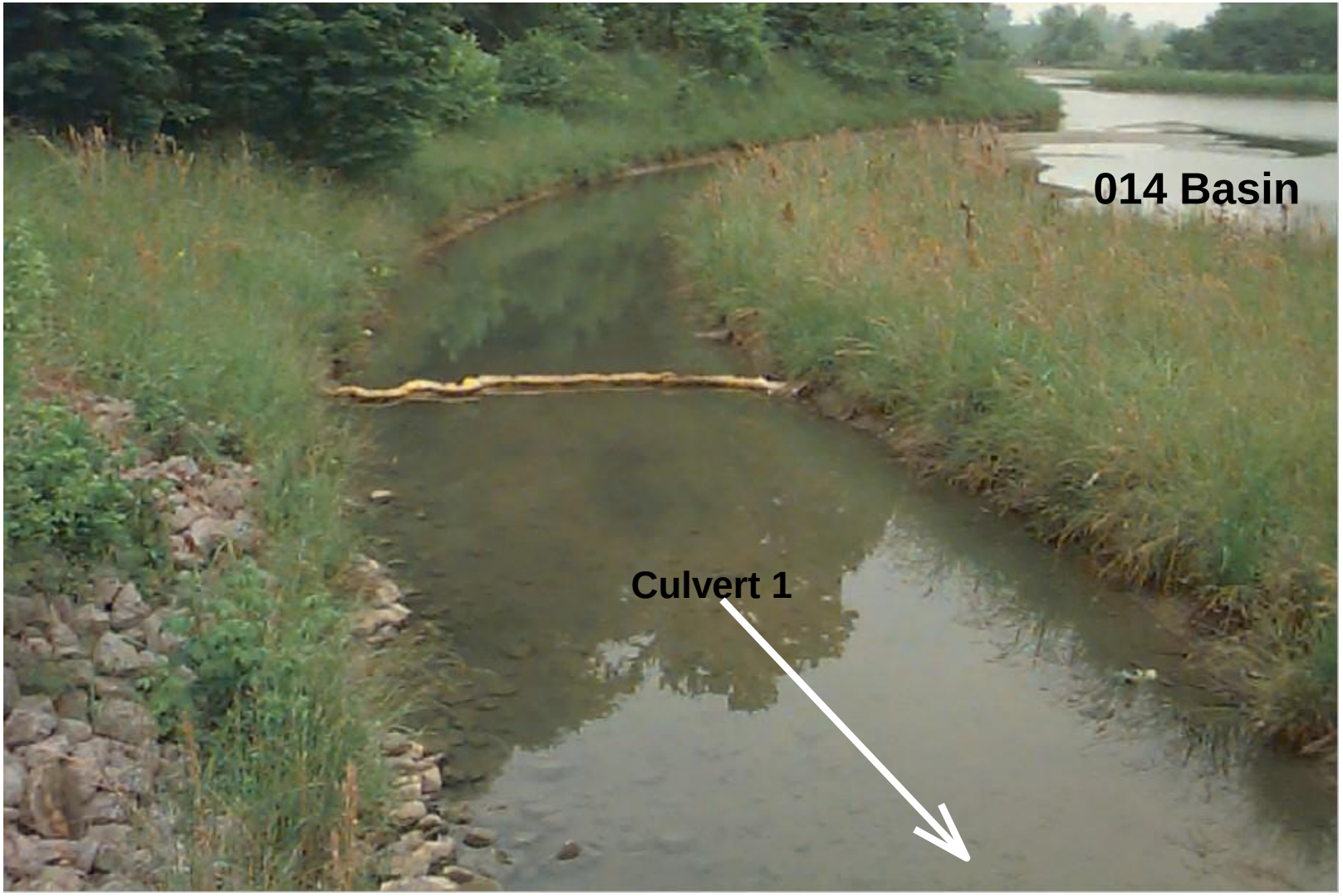
Culvert 1 to 014 Basin



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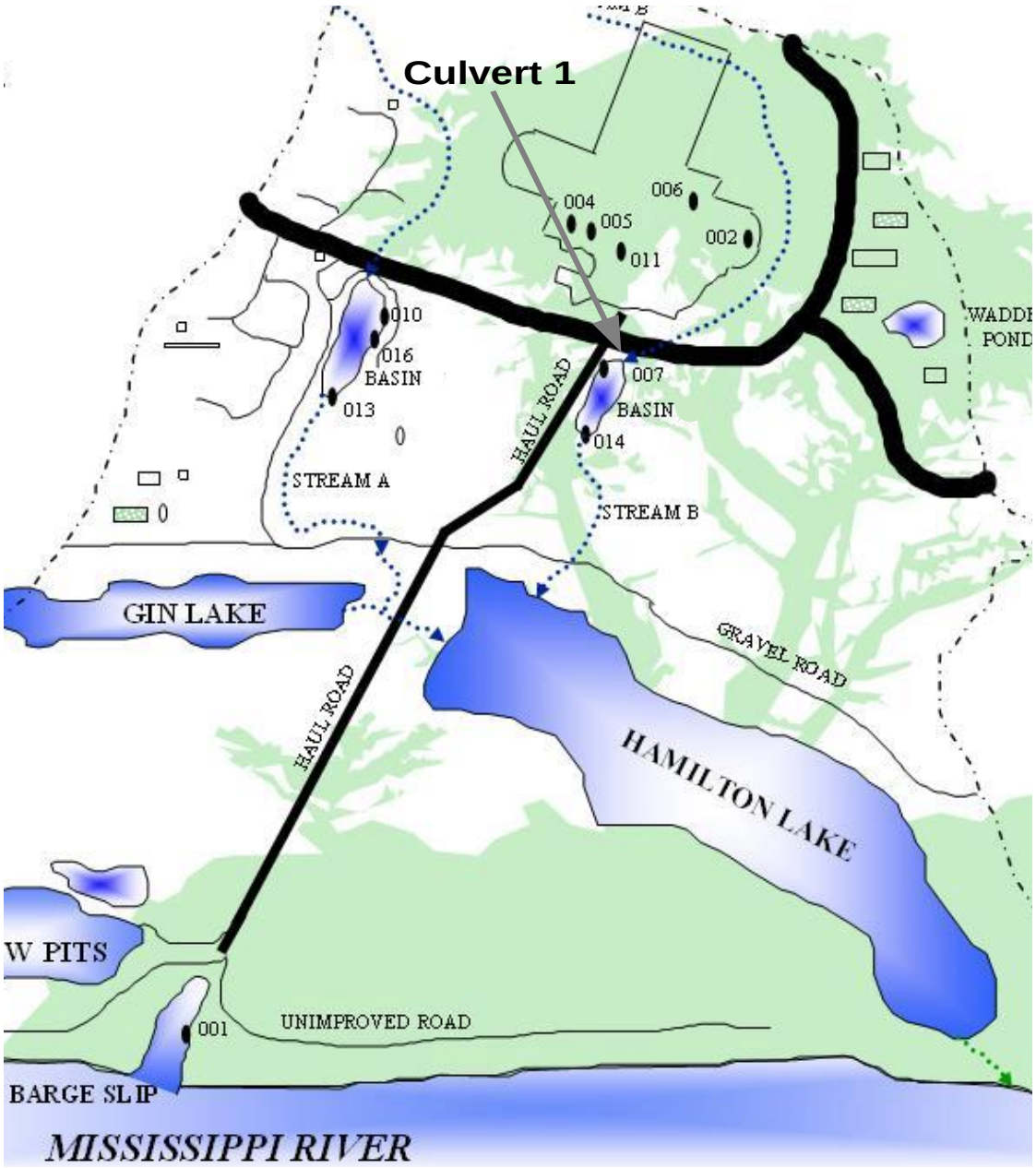
014 Basin to Lake to River



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Assess Dose At Lake (Not River)

- Highest Long Term Environmental Concentrations Would Occur in Lake
- First Body of Water With Sufficient Size to Sustain Year Round Fish or Invertebrate Population
- Assessment at This Location Ensures Dose to Public Unlikely to be Substantially Underestimated

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Assess Dose At Lake

- Most Likely Real Exposure
  - Only After Reaching River
  - Substantial Additional Dilution Would Occur

  Assessment at Lake = Conservative Assessment

- Requires Determination of New Discharge Pathways Dilution Factor

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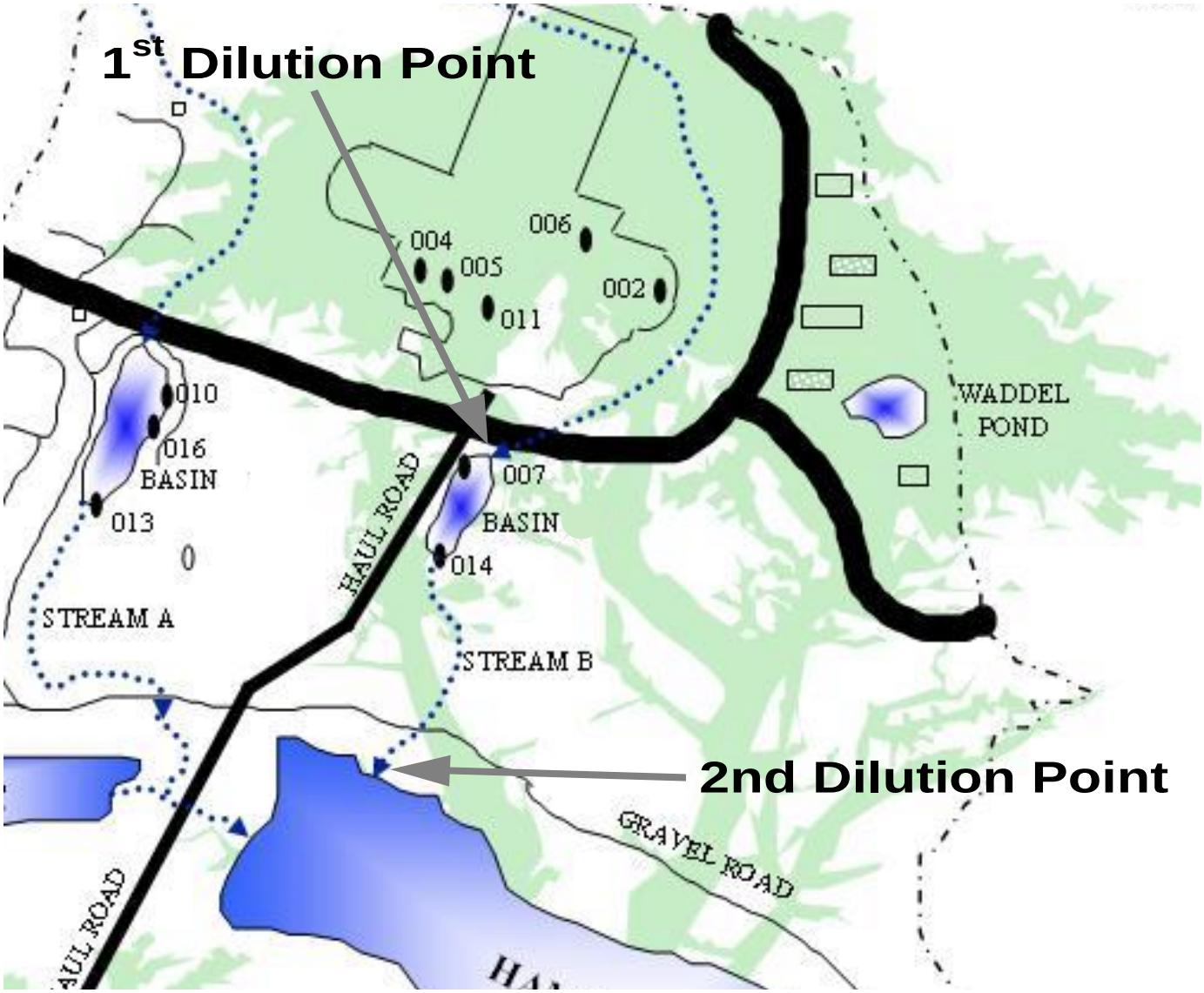
Assumed Dilution Points



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Assumed Future Monitoring Would Take Place at 007 Outfall

- Environmental Concentrations Would Be Difficult to Predict Based on Measurements From Plant Yard
- 007 Outfall Represents Single Entry Point to Environment
- Preferred Monitoring Location

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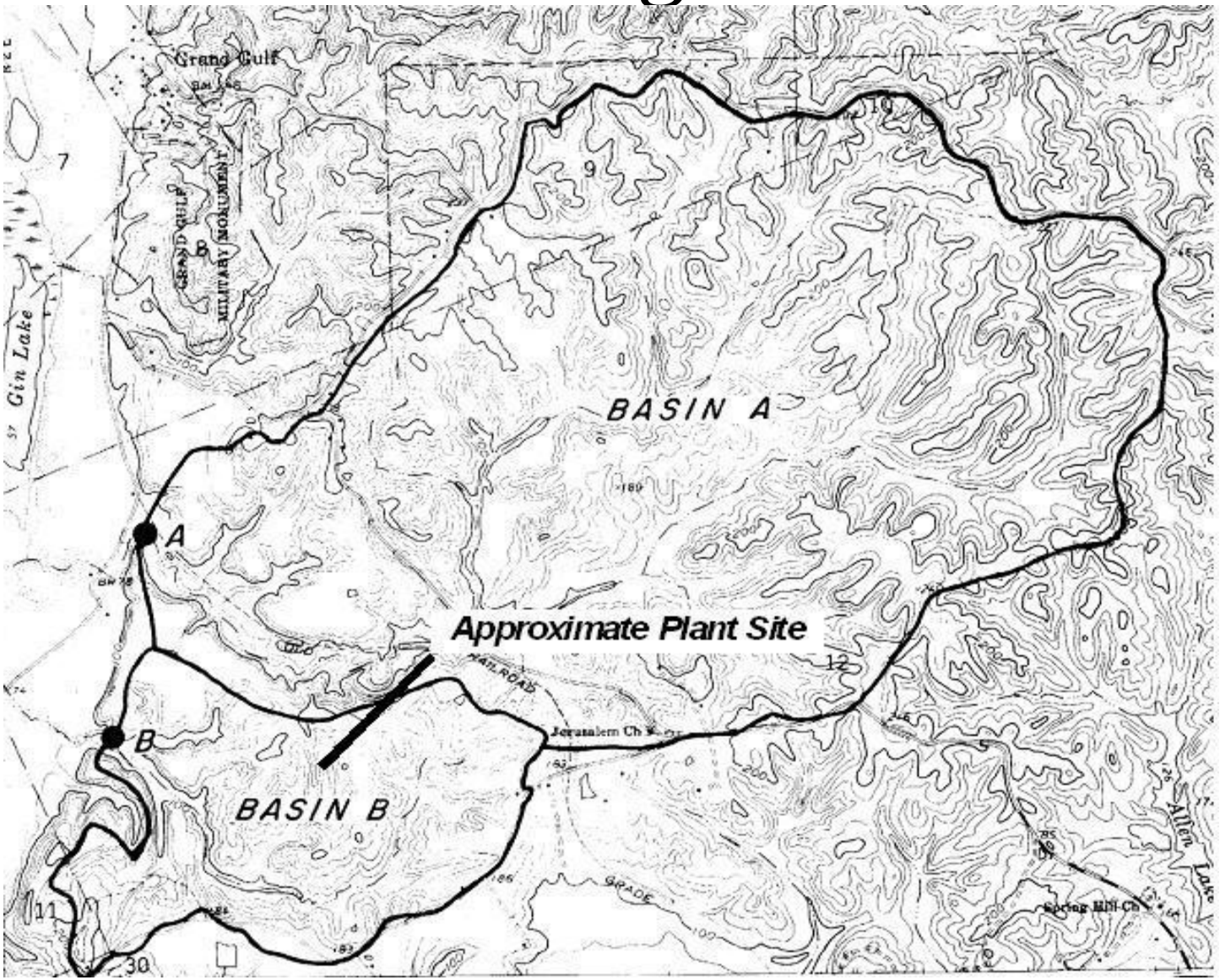
Area Drainage Basins



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Discharge Pathway Drainage Basins

Discharge Pathway	Drainage Basin Description	Drainage Basin Surface Area (acres)
Drainage Basin B Discharge into Basin 014 via Culvert 1	Approximately 0.35 square miles of Drainage Basin B discharges through Culvert 1 (UFSAR section 2.4.3.4.2).	224
Basin 014 Discharge into Hamilton Lake	Remainder of Drainage Basin B (0.26 square miles) plus 2.8 square miles drained by Drainage Basin A. All discharge into Hamilton Lake	1960

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Assumptions for Derivation of Dilution Factor

- Releases to the Environment Would Only Be Significant During Rain Fall
- Ignored Dilution of Hamilton Lake
- Environmental Dilution Driven Only By Runoff From Drainage Basins

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Total Drainage Basin Runoff Depends On

- Total Rainfall Runoff
- Drainage Area
- Type of Cover on Drainage Area

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USDA Natural Resources Conservation Service (NRCS)

- Old Soil Conservation Service
- Field Engineering Handbook
  - Chapter 2 – Estimating Runoff and Peak Discharges
  - NTIS Doc No.PB96-112495
  - www.info.usda.gov/CED/

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$$Runoff\,[inches] = \frac{(P - 0.2 * S)^2}{(P + 0.8 * S)}$$

P = Precipitation in Inches

S = Maximum Potential Retention

$$S = (1000/CN) - 10$$

CN = Runoff Curve Number

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Retention Depends On

- Cover Type
- Cover Treatment
  - Crop Type and Cultivation
- Hydrologic Soil Characteristics
- Impervious Areas
  - Urban and Industrial
- Hydrologic Soil Group

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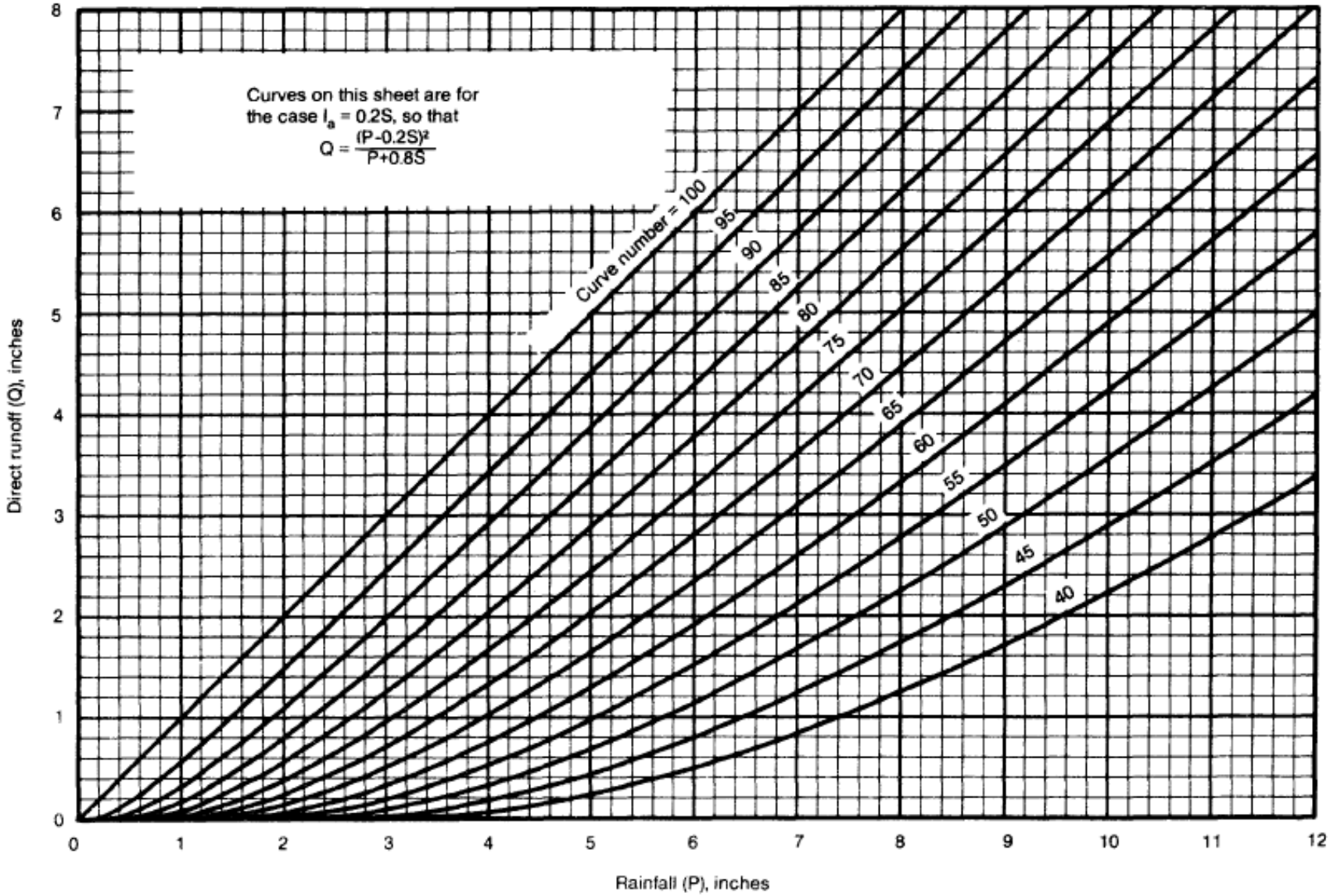
USDA – Runoff Curves



Curve Numbers for Agricultural Land

USDA - NRCS Engineering Field Handbook

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Woods-grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77

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Curve Number Selection - Natural Area

- Hydrologic Soil Group from UFSAR Chapter 2
  - Type “A” and “B” Soils
- Most Conservative
  - Lowest Runoff Potential (Type “A”)
  - Wooded Area
  - Lowest Dilution Volume

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Curve Numbers for Urban Area

USDA - NRCS Engineering Field Handbook

Cover description	Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	A	B	C	D
Fully developed urban areas (vegetation established)				
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50% to 75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc. (excluding right way)	98	98	98	98
Streets and roads:				
Paved; curbs and storm sewers (excluding right-of-way)	98	98	98	98
Paved; open ditches (including right-of-way)	83	89	92	93
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89

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Curve Number Selection – Plant Area

- Most Conservative
  - Paved Parking Lot
  - Highest Runoff Potential
  - Highest Waste Volume

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Dilution Factor 1
007 Outfall to Culvert 1

$$DF_1 = \frac{WA + PY}{PY}$$

DF_1 = Dilution factor for Dilution Pathway 1.
WA = Annual runoff from wooded area around plant.
PY = Annual runoff from plant yard discharging through 007 Outfall.

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Runoff from 007 Outfall into Culvert 1

	Location	P	CN	Runoff (inches)	Drainage Area (acres)	Runoff $ft^3/yr \times 10^6$	Dilution Factor (DF_1)
Lowest Annual Rainfall (1978)	Wooded Area	35	30	17.1	133.8	8.3	1.7
	Plant Yard	35	98	34.8	90.2	11.4	
				Total Culvert 1 Runoff		19.7	
Average Annual Rainfall	Wooded Area	56.6	30	35.8	133.8	17.4	1.9
	Plant Yard	56.6	98	56.3	90.2	18.5	
				Total Culvert 1 Runoff		35.8	

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Dilution Factor 2
Culvert 1 to Lake

$$DF_2 = \frac{\left(V_A + V_R\right) + CV_1}{CV_1}$$

DF_2 = Dilution factor for Dilution Pathway 2.
V_A = Annual runoff volume from Basin A.
V_R = Annual runoff volume from Basin B_R.
CV_1 = Annual runoff volume from Culvert 1.

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Runoff from Culvert 1 into Lake

	Location	P	CN	Runoff (inches)	Drainage Area (acres)	Runoff $ft^3/yr \times 10^6$	Dilution Factor (DF_2)
Lowest Annual Rainfall - 1978	Culvert 1 Exit Flow	-	-	-	-	19.7	7.2
	Basin A + Basin B_R	35	30	17.1	1952	121.5	
		Total Runoff Into Hamilton Lake				141.2	
Average Annual Rainfall	Culvert 1 Exit Flow	-	-	-	-	35.8	8.1
	Basin A + Basin B_R	56.6	30	35.8	1952	253.8	
		Total Runoff Into Hamilton Lake				289.6	

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Dilution Factors for Discharge from 007 Outfall into Lake

	DF_1 007 Outfall to Culvert 1	DF_2 Culvert 1 to Hamilton Lake	DF_{HL} 007 Outfall to Hamilton Lake
Lowest Annual Rainfall 1978	1.7	7.2	12.2
Average Annual Rainfall 1972-1991	1.9	8.1	15.4

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Surveillance Recommendations

- Provide Monthly Grab Sample at 007 Outfall
- Could Monitor 007 Outfall at Effluent LLD
- Better Choice - Monitor 007 Outfall at Environmental LLD
  - Uncontrolled Release Directly to Environment
  - Lower Monitoring Level Allows for Trending and Early Warning
  - Demonstrates Increased Diligence

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Monitor and Trend

- 007 Outfall Tritium Concentrations
- 007 Outfall Discharge Flow Rate
- 007 Outfall Discharge Volume
- Site Precipitation
  - Determines Runoff Dilution Volume
- Examine Correlation Between Precipitation and 007 Tritium Concentrations

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