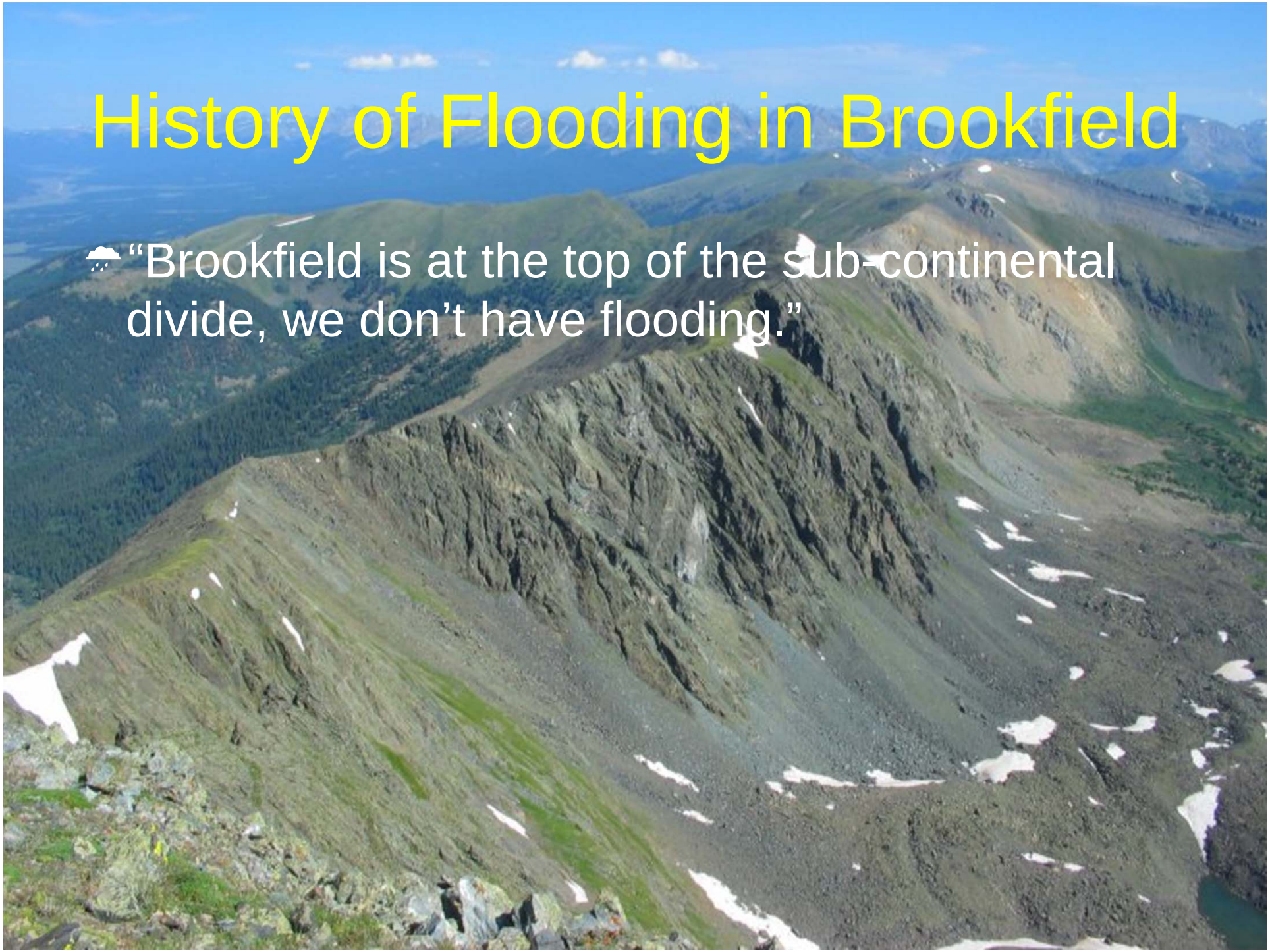

Are we misleading the public by calling Extreme Rain Events the “100-Year Storm”?
Changing the scale from
Rarity … to … Severity!

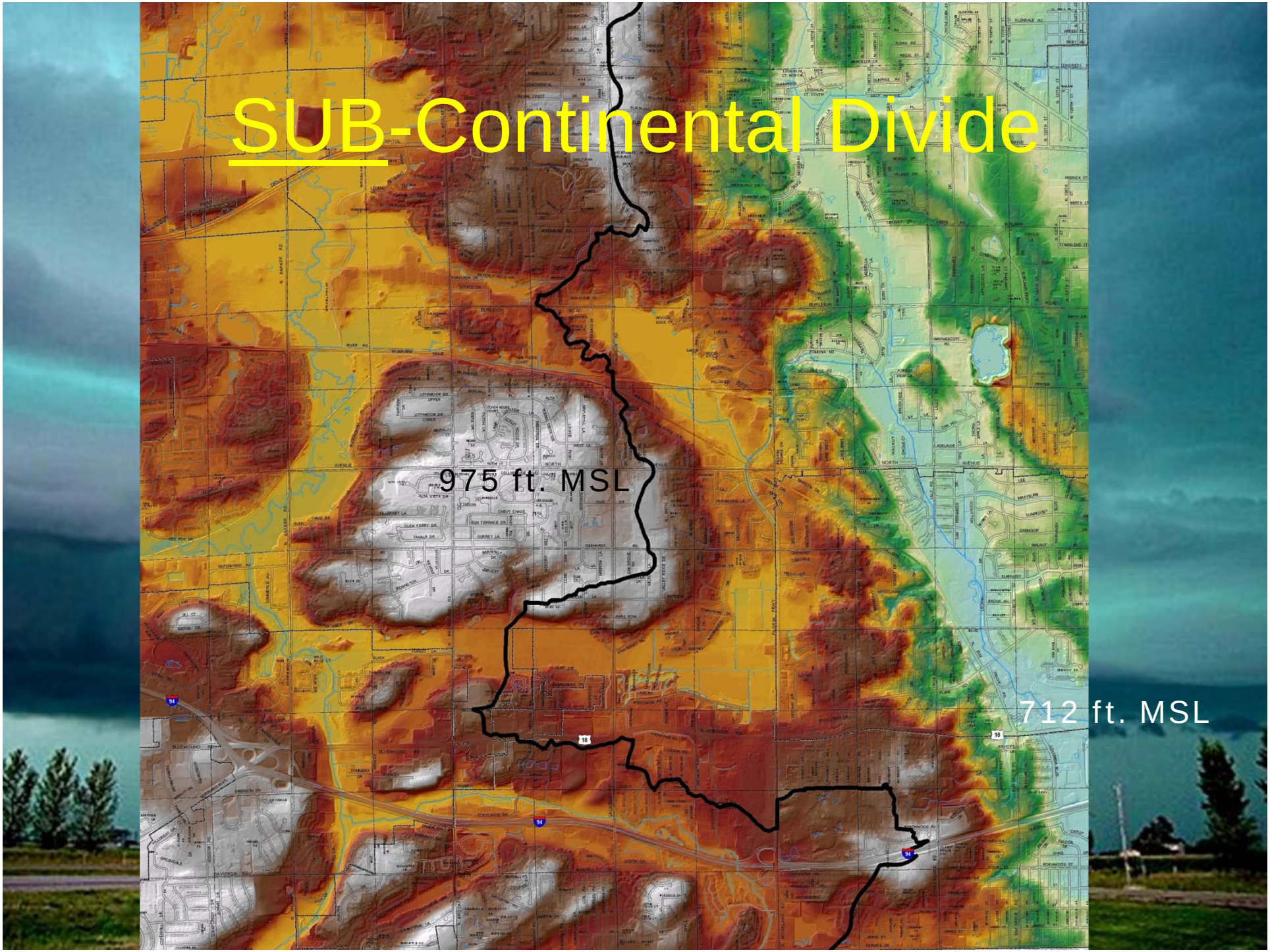
Where Am I Going With This?

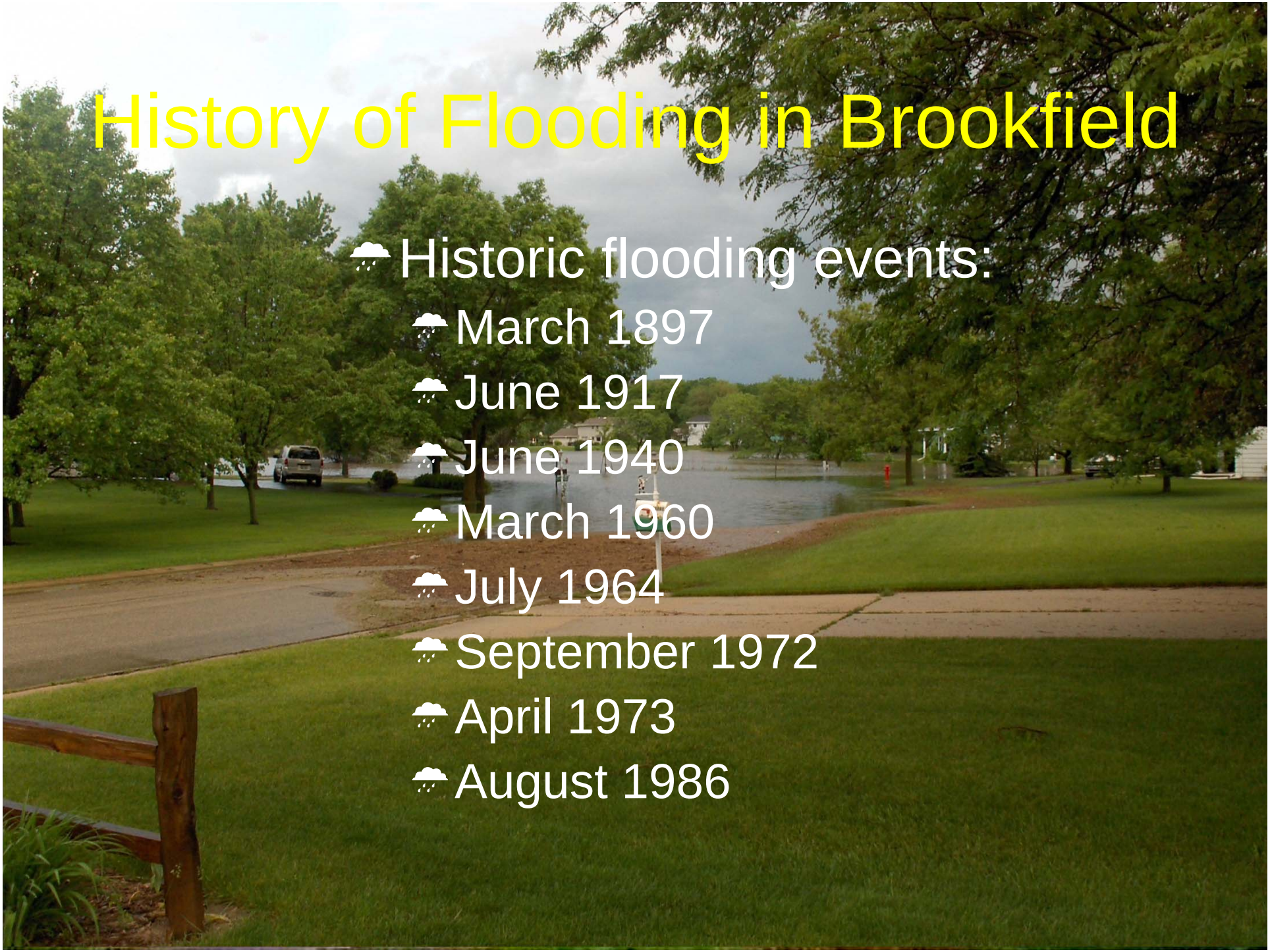
- Need to know where we have been

History of Flooding in Brookfield

- “Brookfield is at the top of the sub-continental divide, we don’t have flooding.”

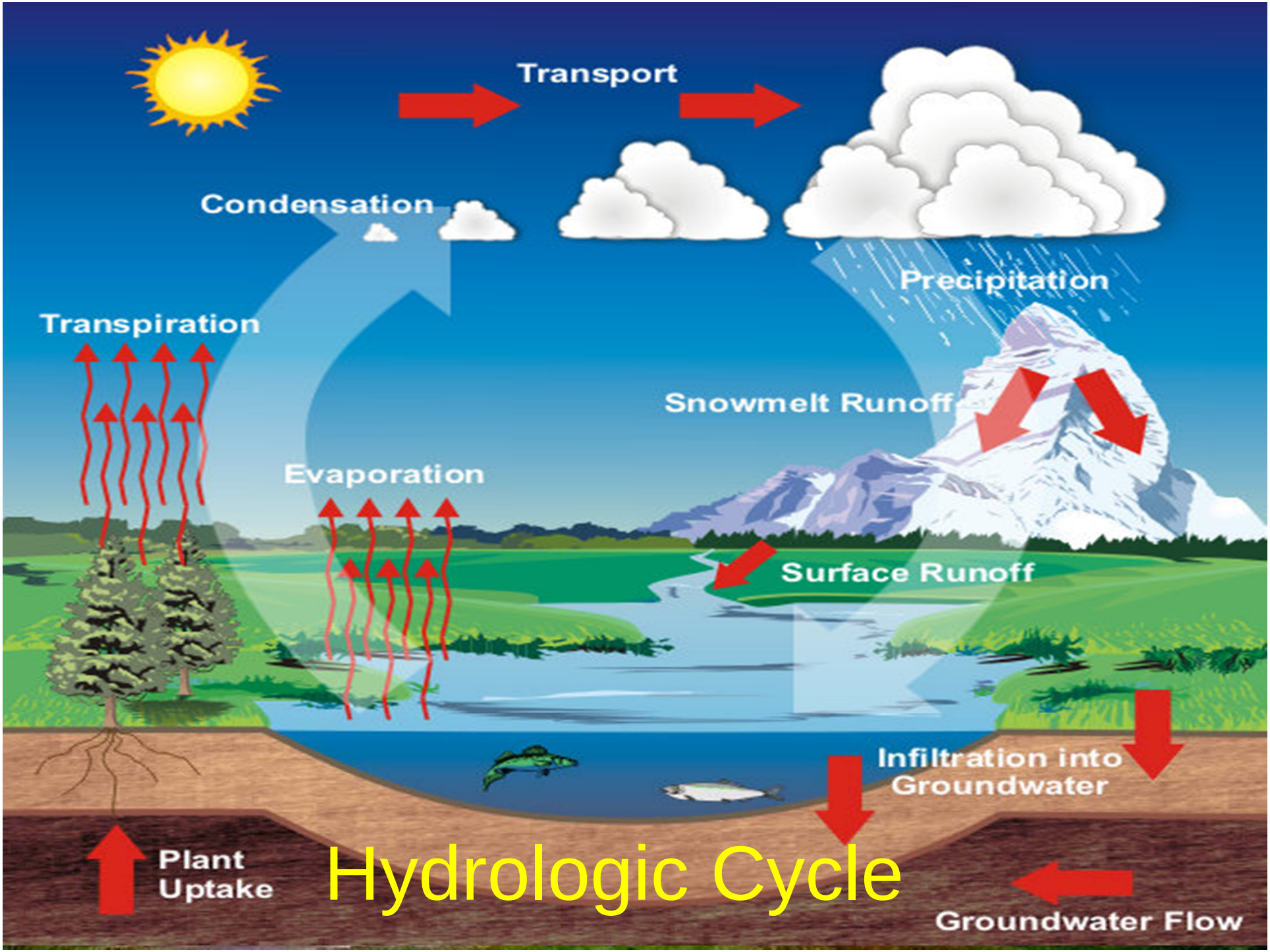



SUB-Continental Divide
975 ft. MSL
712 ft. MSL

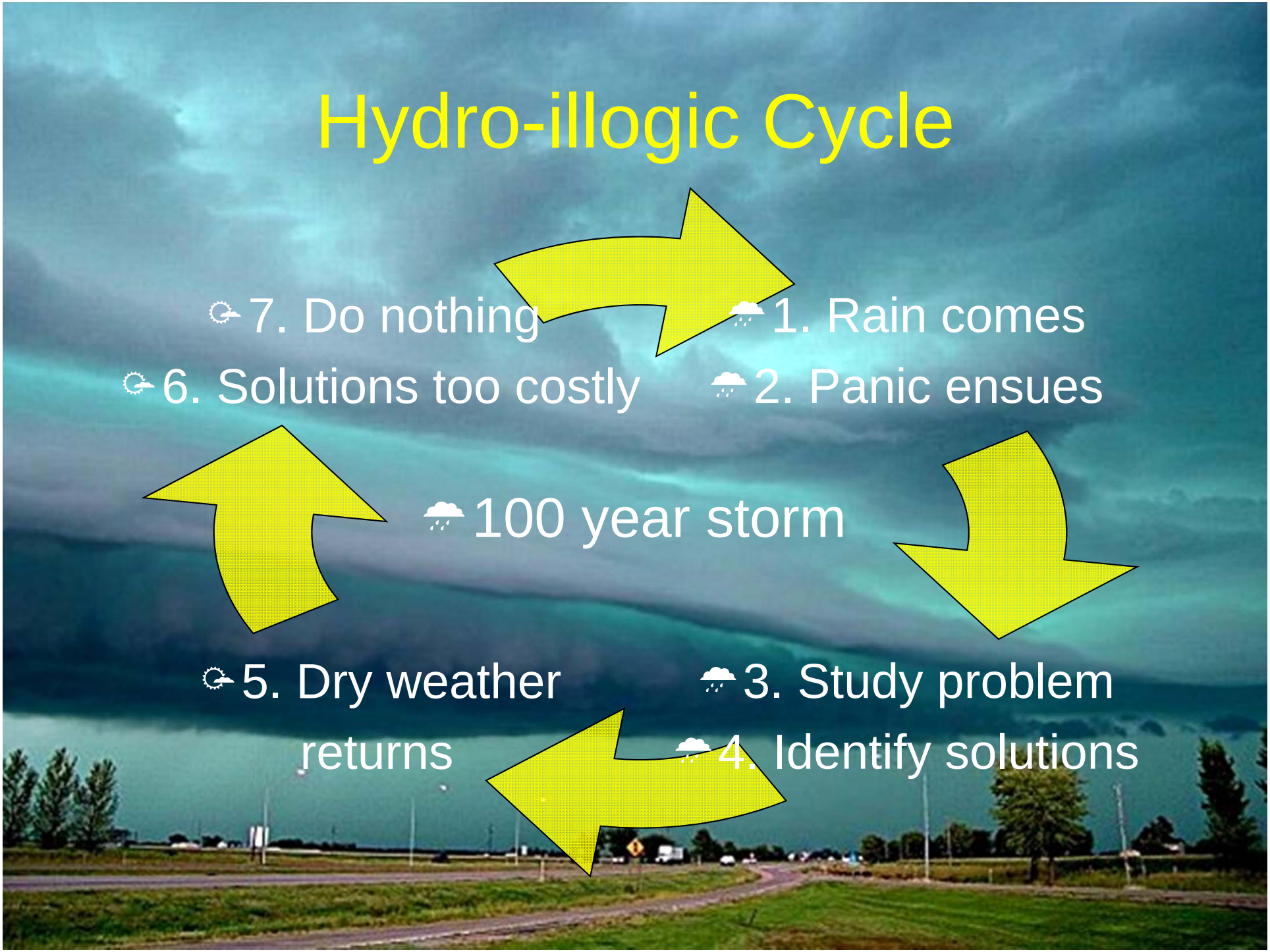


History of Flooding in Brookfield

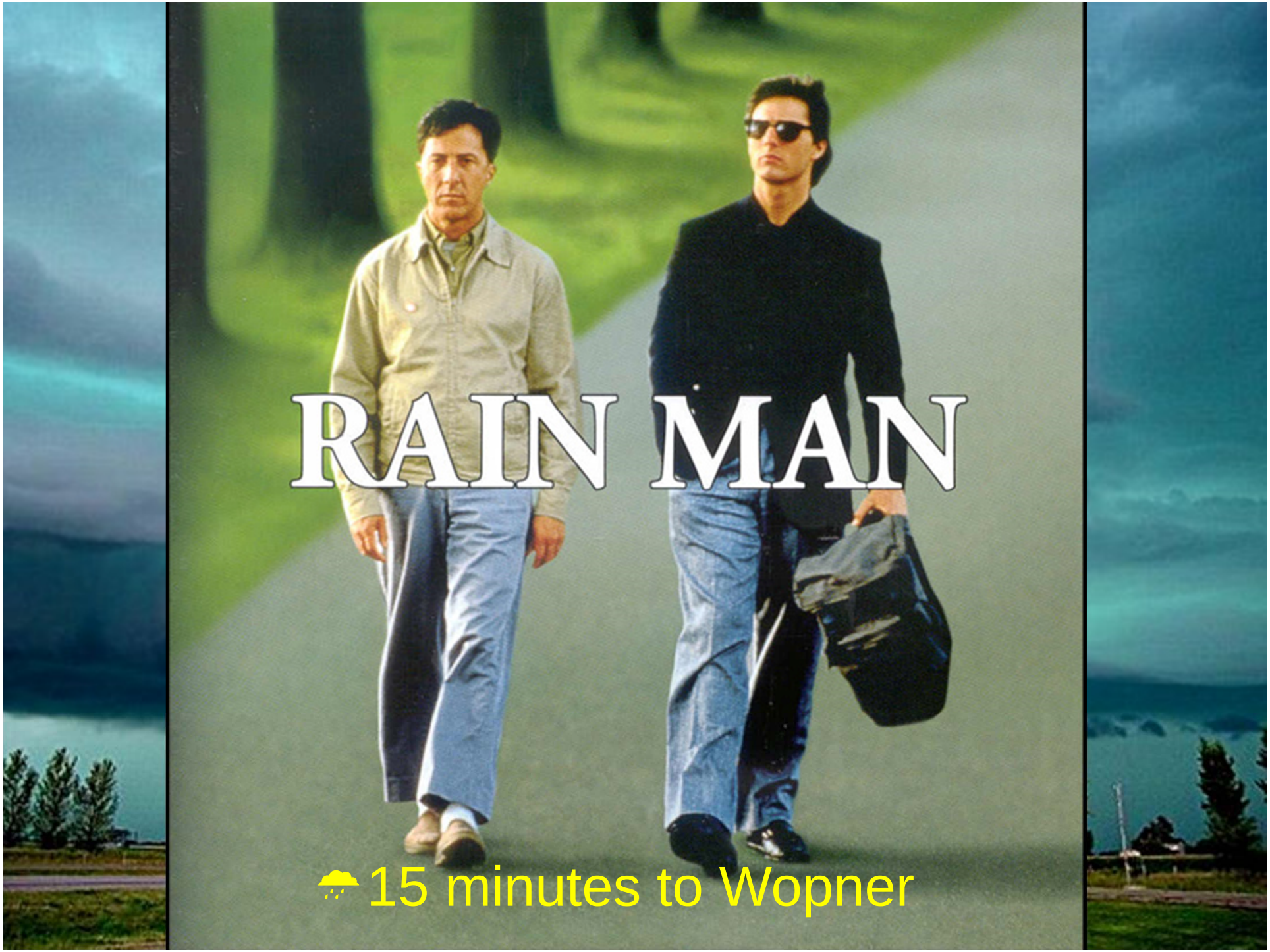
- Historic flooding events:
  - March 1897
  - June 1917
  - June 1940
  - March 1960
  - July 1964
  - September 1972
  - April 1973
  - August 1986


Transport
Condensation
Precipitation
Transpiration
Snowmelt Runoff
Evaporation
Surface Runoff
Infiltration into Groundwater
Plant Uptake
Hydrologic Cycle
Groundwater Flow

Hydro-illogic Cycle

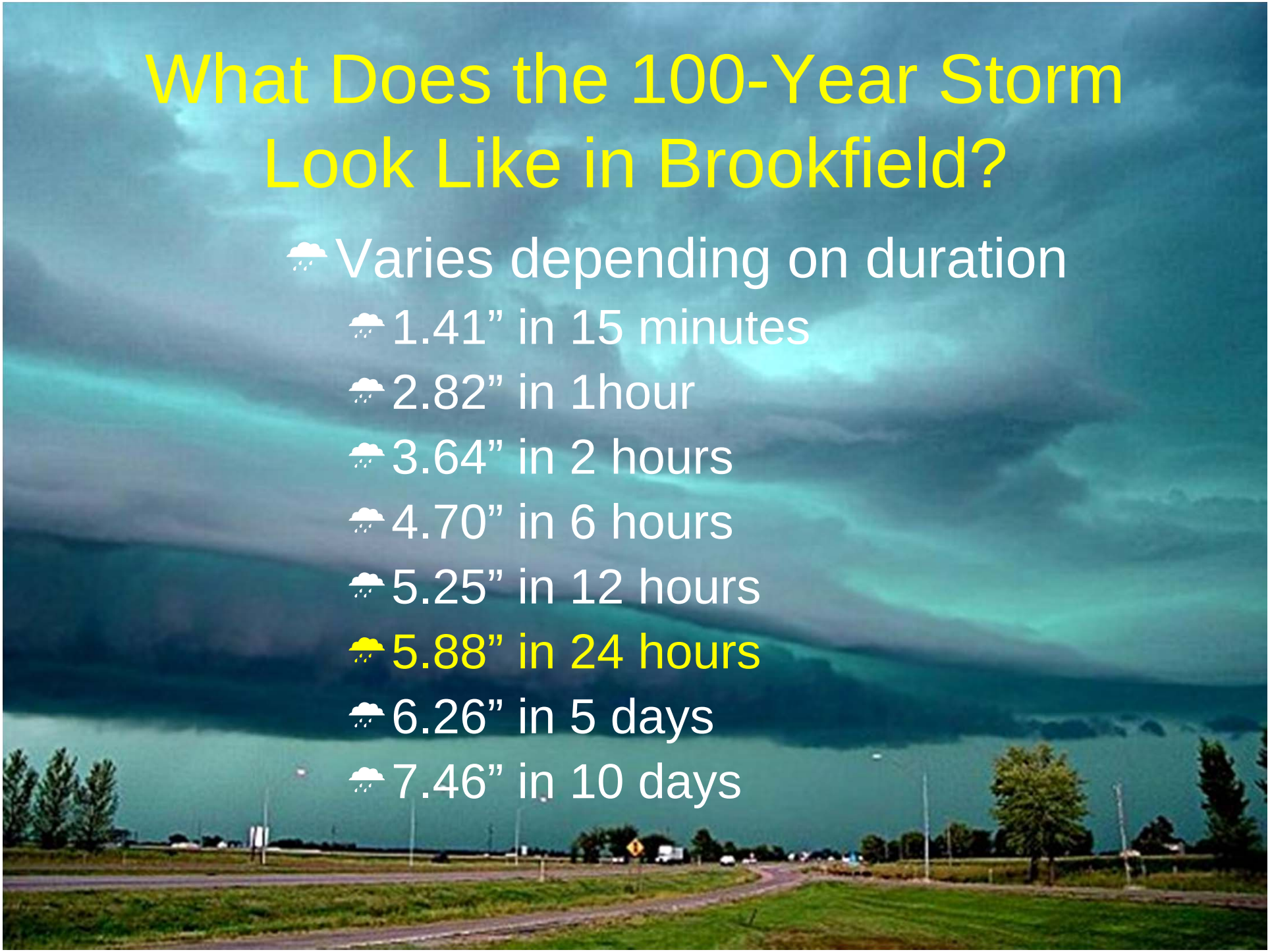


Who am I, and why am I here?


RAIN MAN
15 minutes to Wopner

Victim of Hydro-illogic Cycle

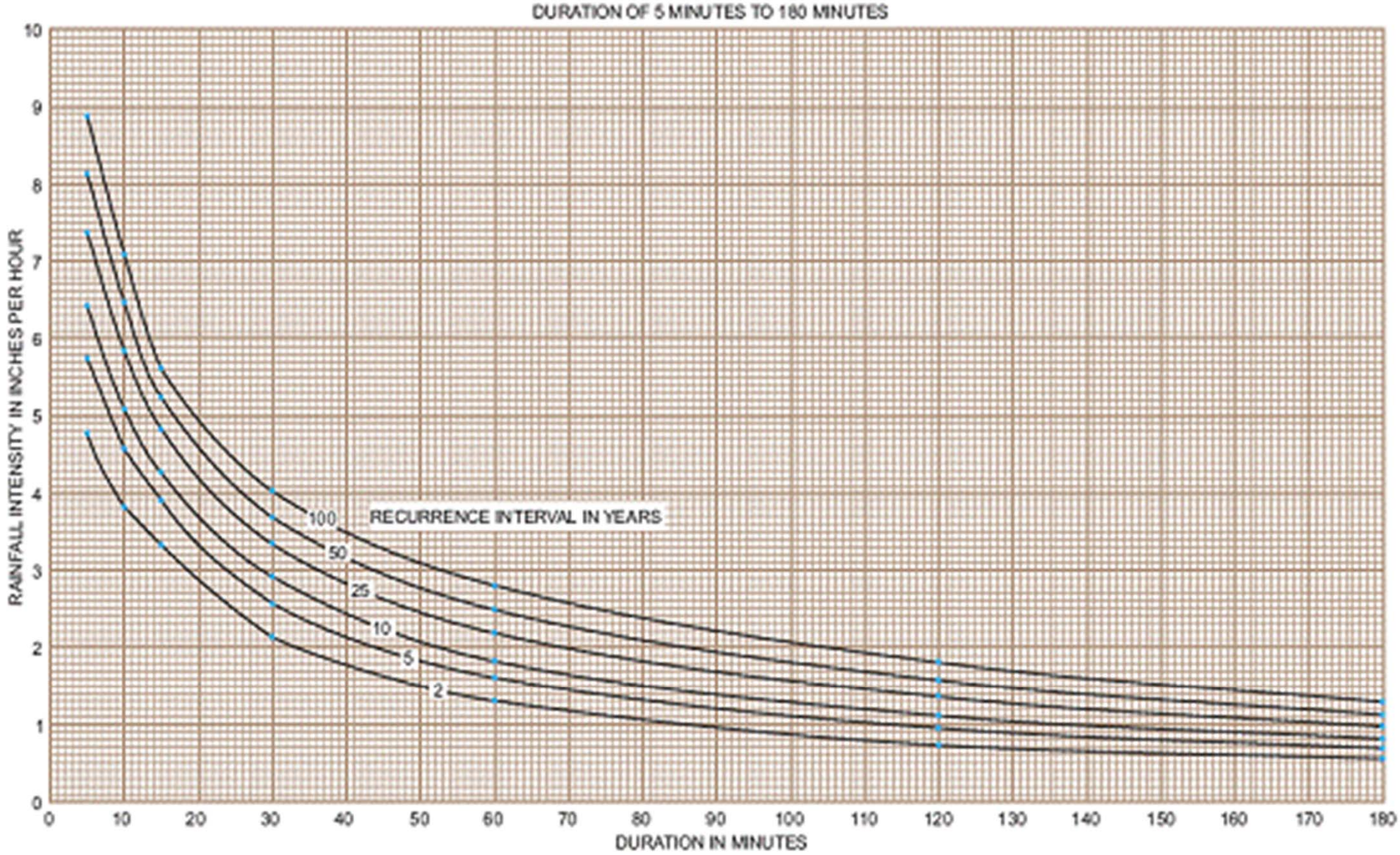
- Recent history of flooding in Brookfield
  - June 20 - 21, 1997 – 6” in 26 hours
  - August 6, 1998 – 11.35” in 8 hours
  - June 7 - 8, 2008 – 5.8” in 24 hours
  - June 19, 2009 – 4.8+” in 3 hours
  - July 22, 2010 – 6.2” in 20 hours
- Five 100-year storms or larger in 14 years



What Does the 100-Year Storm Look Like in Brookfield?

- Varies depending on duration
  - 1.41” in 15 minutes
  - 2.82” in 1hour
  - 3.64” in 2 hours
  - 4.70” in 6 hours
  - 5.25” in 12 hours
  - 5.88” in 24 hours
  - 6.26” in 5 days
  - 7.46” in 10 days

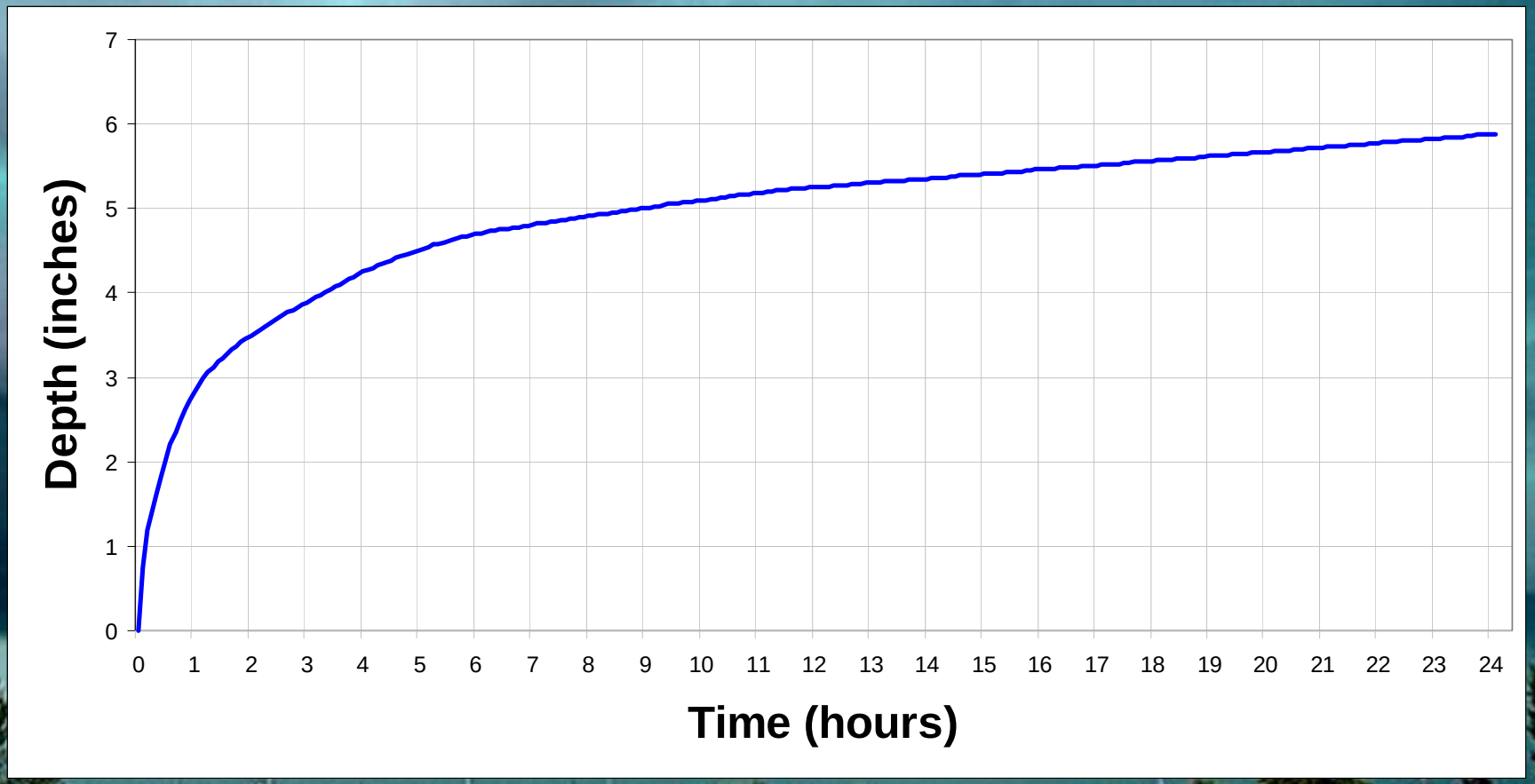
POINT RAINFALL INTENSITY—DURATION—FREQUENCY CURVES FOR MILWAUKEE, WISCONSIN[a]



[a]*The curves are based on Milwaukee rainfall data for the 108-year period of 1891 to 1998.*

Source: Rodgers and Potter and SEWRPC

100 year storm - Graphically



Why Call Them 100-Year Storms?

Milwaukee

Las Vegas

Seattle

- 2” rains are different depending where you are
- Need something that can be used consistently across the country
- Account for variability in these storms by region

How can two 100-year storms occur in a row?

- Oops, let's change that
- 1% probability storm
- Aren't we clever?
- Public knows 1% = 1/100
- They figure out that it's the 100-year storm
- Now they feel like we tried to deceive them – hiding behind probabilities

Probability of the 100-Year Storm

- Probability of 100-year event: p = 0.01
- 100-year event occurring three years in a row?
- $p^3 = (0.01)^3 = 0.000001$ or 1 in a million
- Not always intuitive
- Probability of 100-year event occurring at least once in 100 years?
- $1-(1-p)^{100} = 1-(0.99)^{100} = 1-0.366 = 63.4\%$
- Public thinks it would always occur once every 100 years

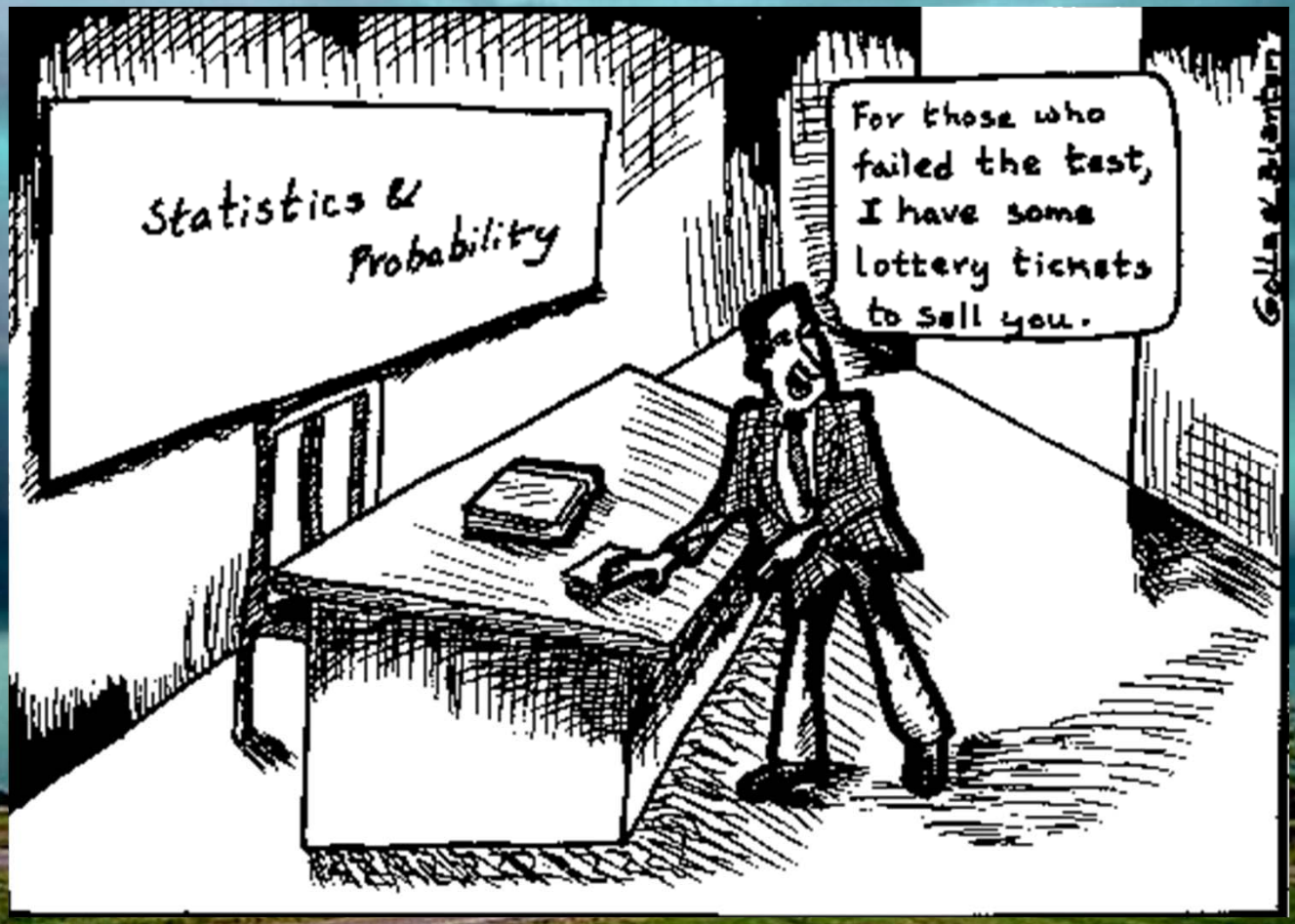
Binomial Probability Applied to Extreme Events

- More complex relationships
- 100-year event occurs 5 times in 14 years?

  $n!*p^{Y}*(1-p)^{(n-Y)} / (Y!)*(n-Y)!$
- $14!*0.01^{5}*(0.99)^{9} / 5!*9!$ = 1 in 5.5 million
- Is this pretty rare?
- Consider what people are willing to gamble on

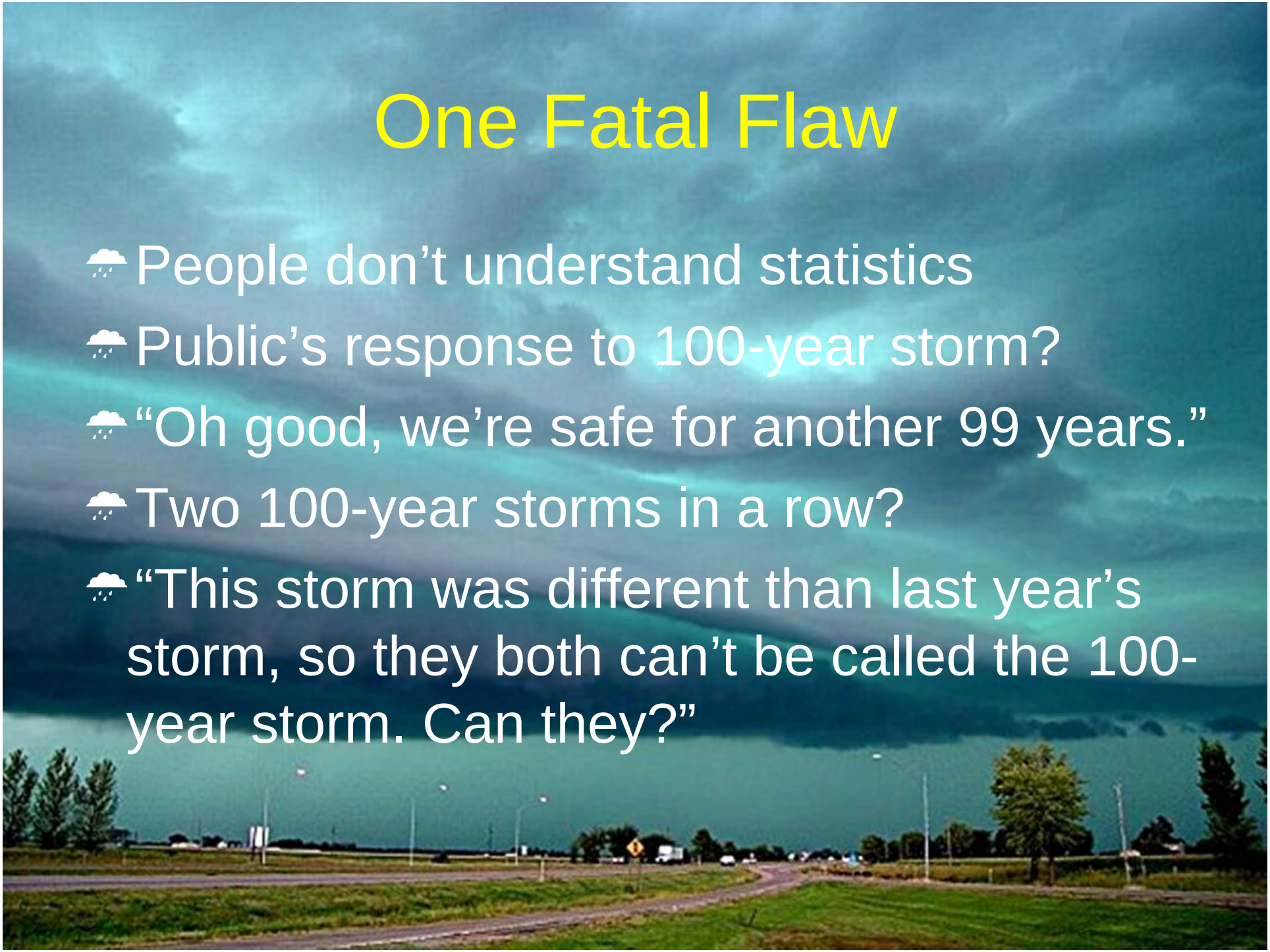
Probability and Statistics

- Winning the Powerball Lottery: 1 in 195 million

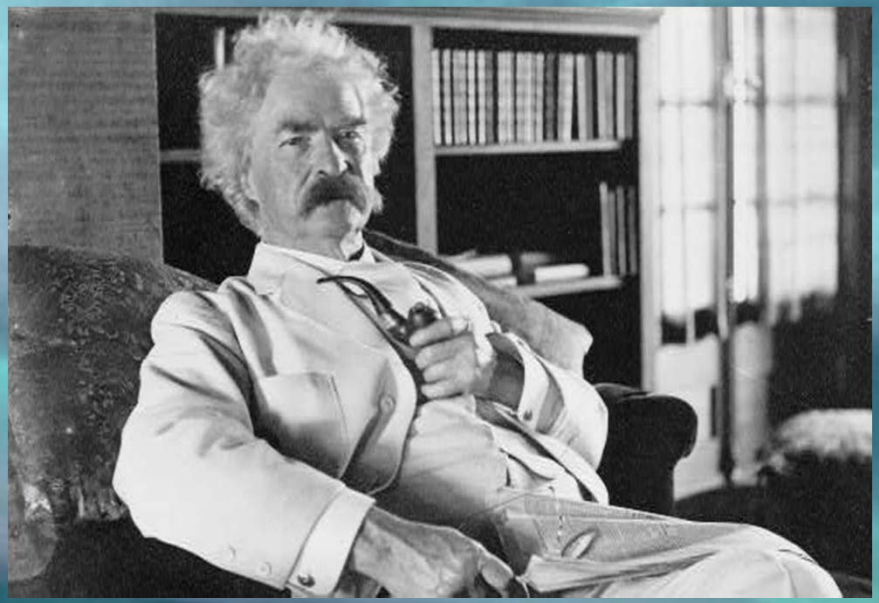


One Fatal Flaw

- People don't understand statistics
- Public's response to 100-year storm?
- "Oh good, we're safe for another 99 years."
- Two 100-year storms in a row?
- "This storm was different than last year's storm, so they both can't be called the 100-year storm. Can they?"

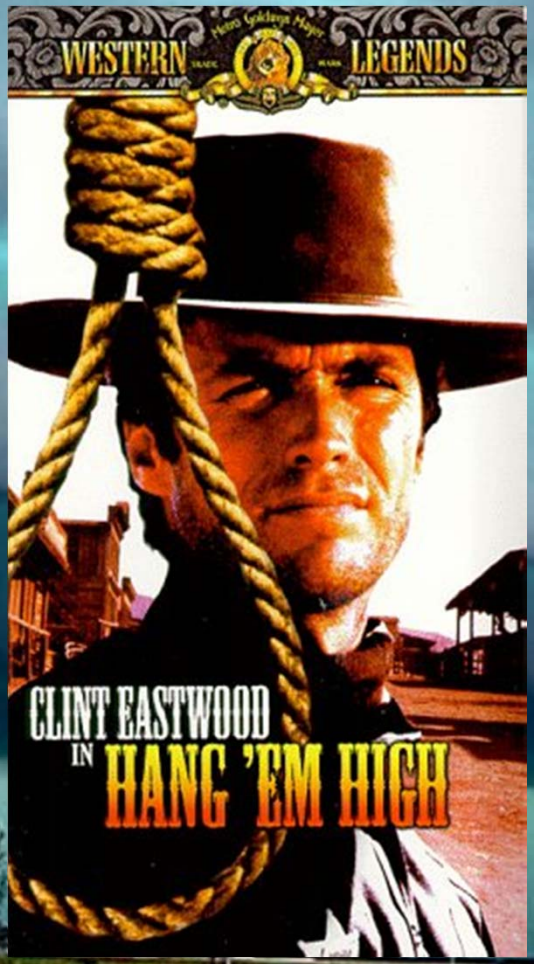


Public Confusion



- Mark Twain said, “The more you explain it, the more I don't understand it”
- Public more likely to respond this way

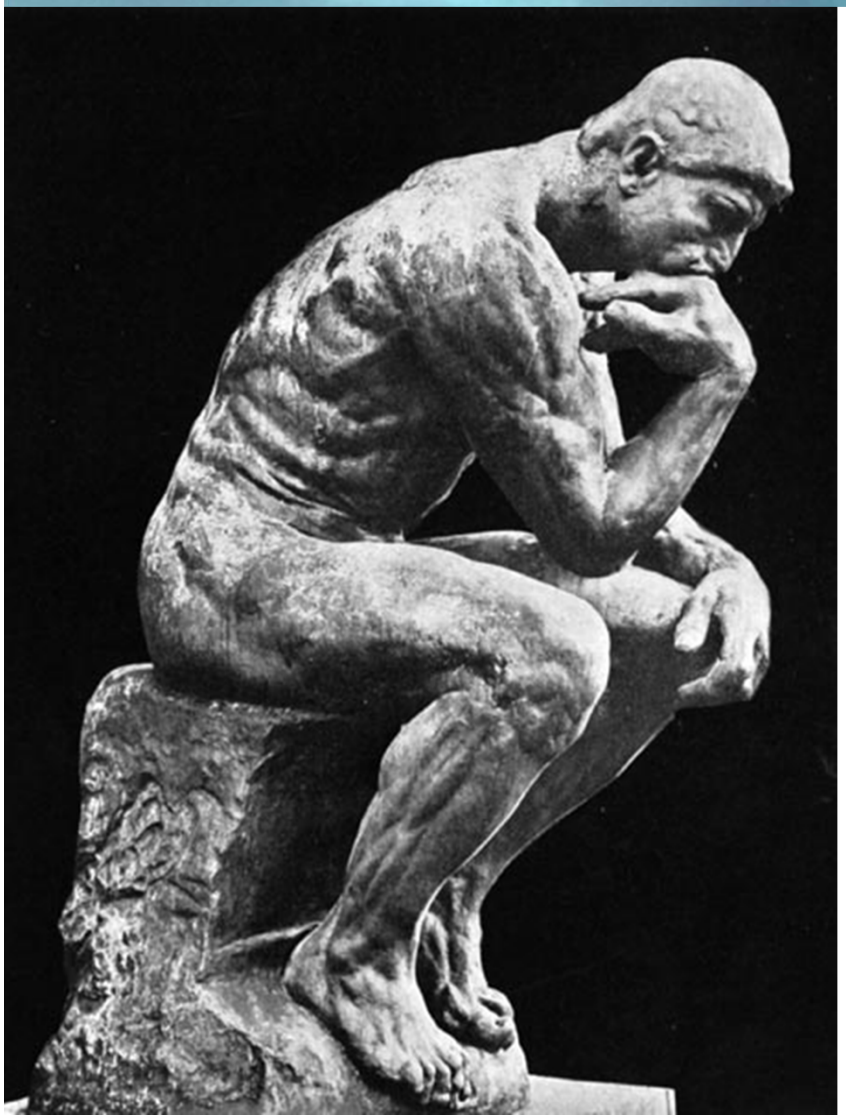
Public Response



- Disbelief
- Disgust
- Cynicism
- Look for someone to blame
- Affects our credibility
- Less likely to take our advice in future

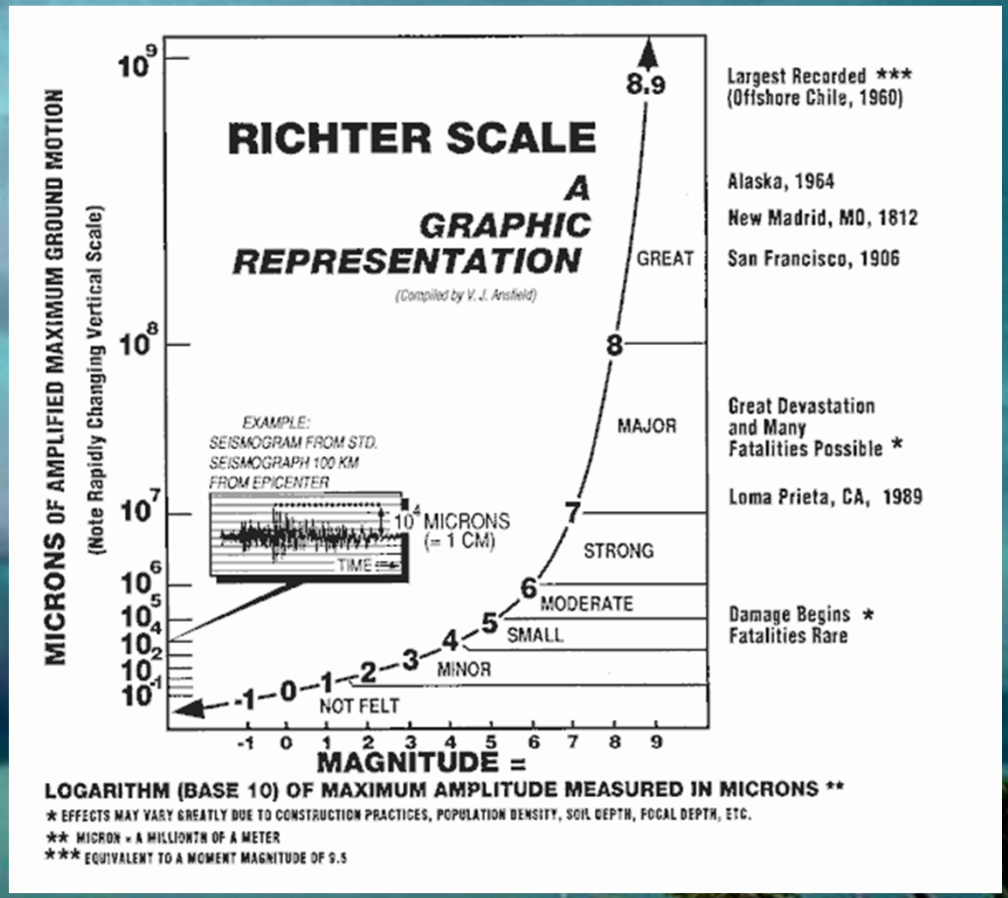
Isn’t it Time We Start Thinking Outside of the Box?

Is There a Better Way?

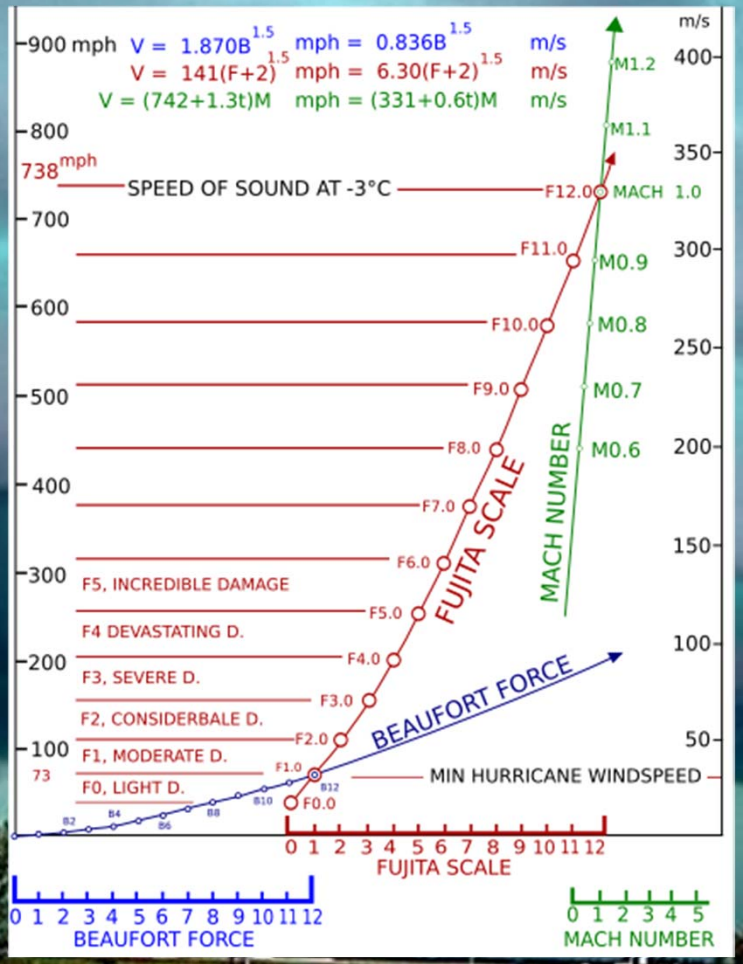


Rating Other Natural Disasters

- Earthquakes
- Richter scale
- Measurement of
  - Energy released
  - Strength
  - Duration of its seismic waves



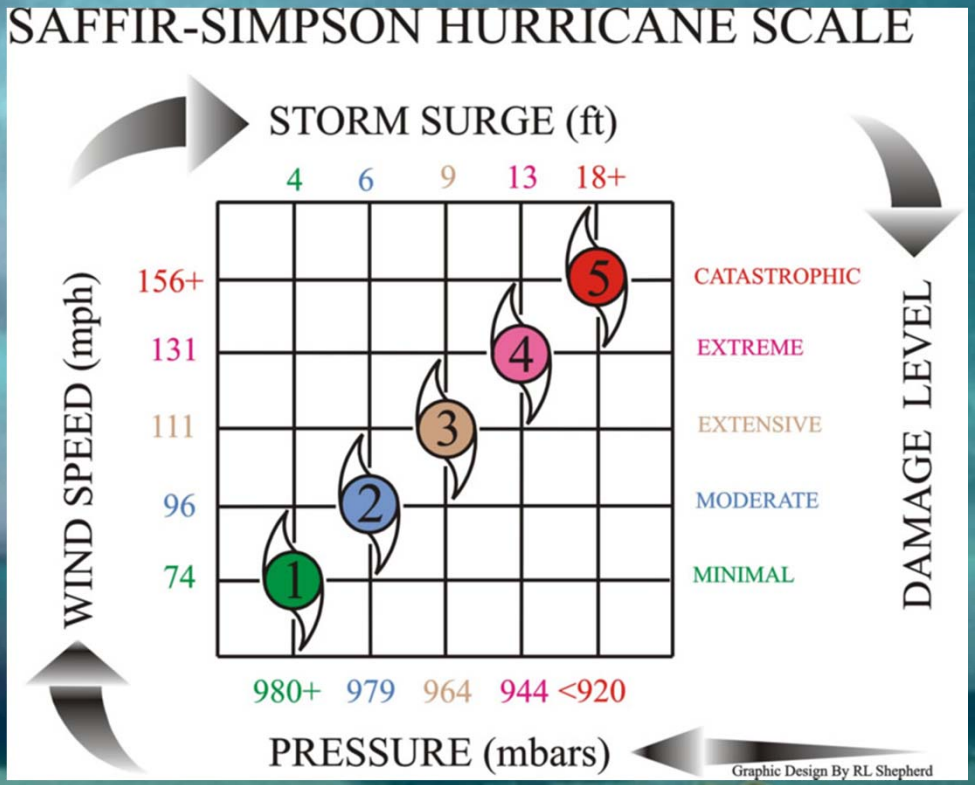
Rating Other Natural Disasters



- Tornadoes
- Fujita scale (enhanced since 2007)
- Measurement of
  - Intensity
  - Area affected

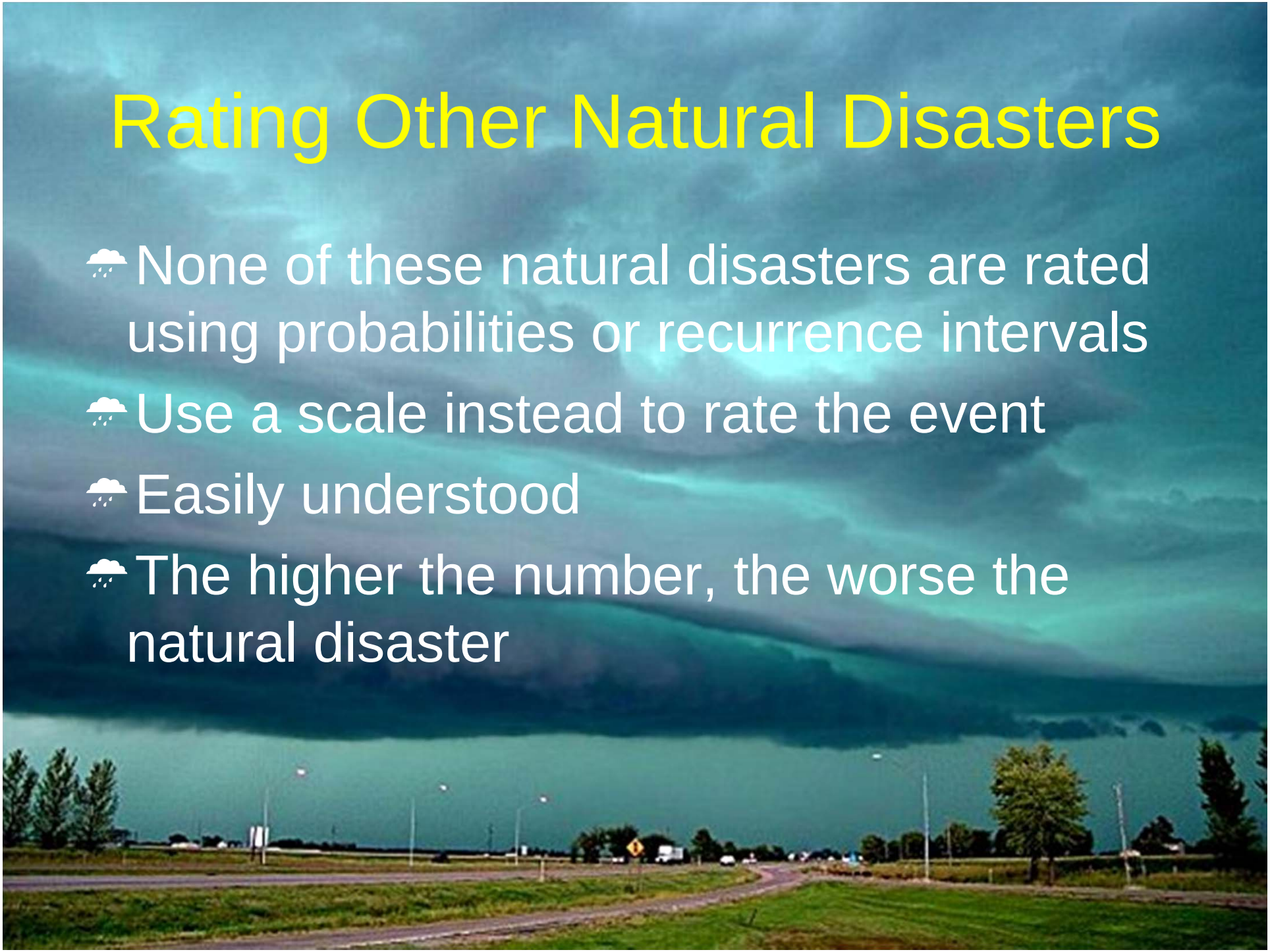
Rating Other Natural Disasters

- Hurricanes
- Saffir- Simpson scale
- Measurement of
  - Barometric pressure
  - Wind speed
  - Storm surge



Rating Other Natural Disasters

- None of these natural disasters are rated using probabilities or recurrence intervals
- Use a scale instead to rate the event
- Easily understood
- The higher the number, the worse the natural disaster



Measure of Severity – Not Rarity

- Severity indicates that people need to protect themselves from severe storms
- Severity does not imply that they could not happen year after year
- Rarity implies that you're safe until the end of the recurrence interval
- Public less apt to protect themselves against another intense rain event
- Perpetuates the hydro-illogic cycle

Revise Terminology for Rain Events

- Keep It Simple
  S_ _ _ _ _
- Use recurrence intervals as basis
- Don’t call them 100-year storms
- Use a scale like other natural disasters
- Focus on severity, not rarity

Existing Rainfall Frequencies and Rainfall Depths for Southeastern Wisconsin

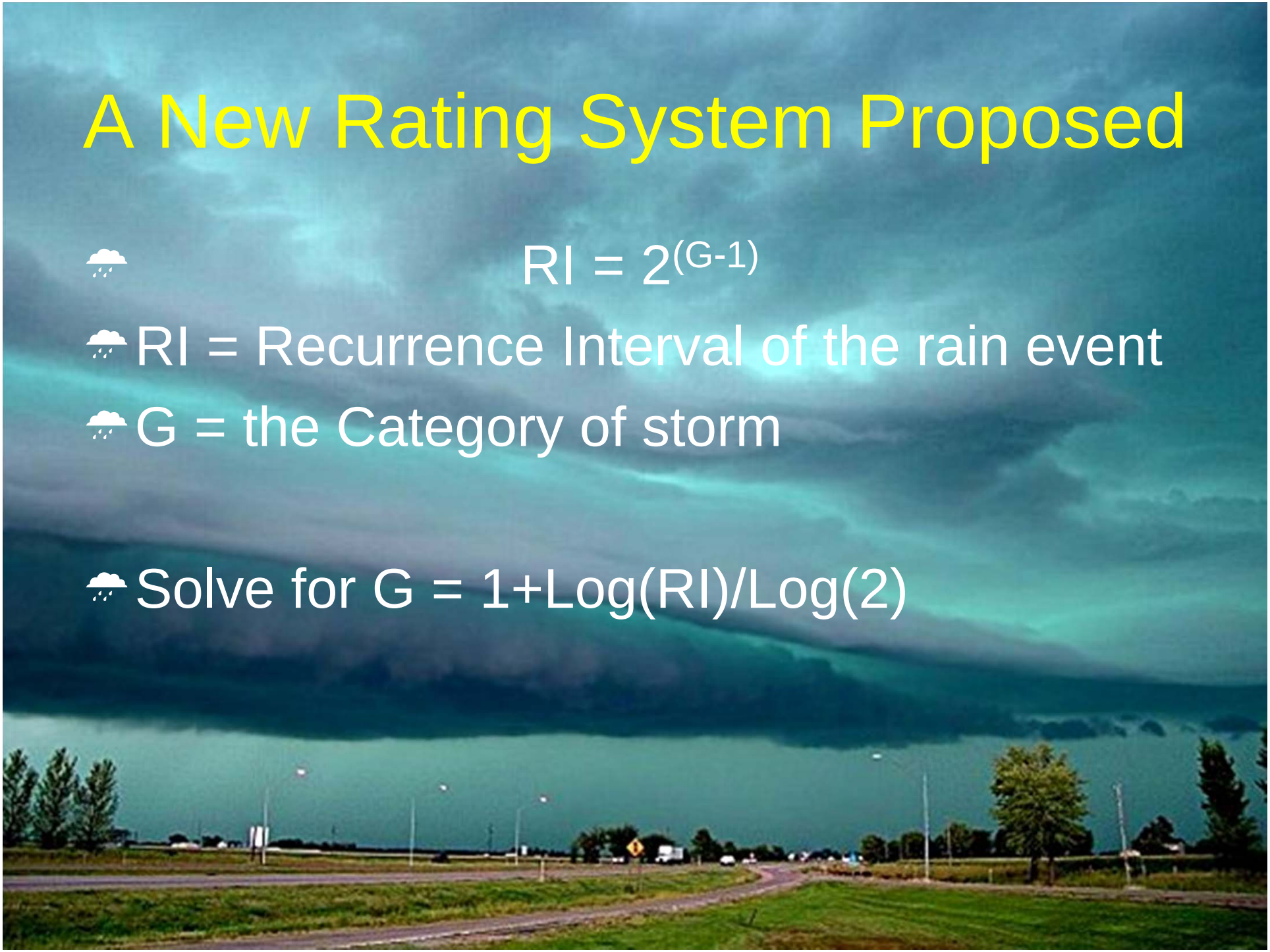
Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	1.31	1.60	1.84	2.20	2.50	2.82
2 hour	1.54	1.93	2.23	2.73	3.16	3.64
3 hour	1.68	2.07	2.40	2.93	3.39	3.89
6 hour	1.95	2.40	2.79	3.44	4.03	4.70
12 hour	2.24	2.74	3.17	3.89	4.53	5.25
24 hour	2.57	3.14	3.62	4.41	5.11	5.88
2 day	3.04	3.71	4.20	4.94	5.53	6.13
3 day	3.29	3.94	4.40	5.09	5.63	6.17
5 day	3.77	4.42	4.84	5.43	5.86	6.26
10 day	4.68	5.42	5.89	6.55	7.03	7.46

Rainfall data is based on Milwaukee rainfall data for the 108-year period of 1891 to 1998. Source: Rodgers, Potter, and SEWRPC

A New Rating System Proposed

- $RI = 2^{(G-1)}$
- RI = Recurrence Interval of the rain event
- G = the Category of storm

- Solve for G = 1+Log(RI)/Log(2)



Placing the Recurrence Interval Storm into the New Rating System

Recurrence Interval Rain Storm	G-factor
2 year storm	2
5 year storm	3.32
10 year storm	4.32
25 year storm	5.64
50 year storm	6.64
100 year storm	7.64

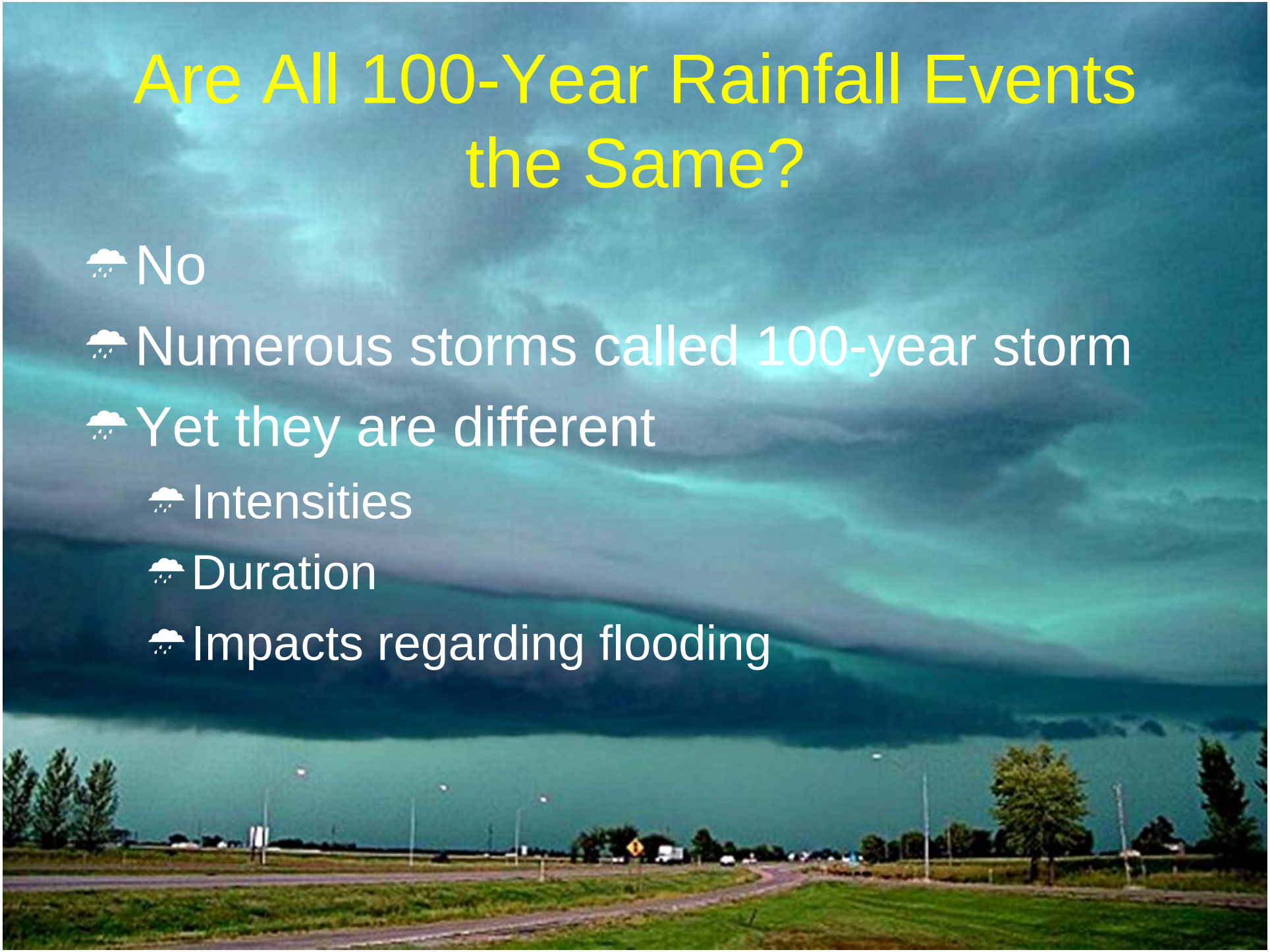
Placing the Recurrence Interval Storm into the New Rating System

	Recurrence Interval					
Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	2	3	4	6	7	8
2 hour	2	3	4	6	7	8
3 hour	2	3	4	6	7	8
6 hour	2	3	4	6	7	8
12 hour	2	3	4	6	7	8
24 hour	2	3	4	6	7	8

- Focus just on 24 hour duration events and smaller since most people think in terms of a single day for rain total

Are All 100-Year Rainfall Events the Same?

- No
- Numerous storms called 100-year storm
- Yet they are different
  - Intensities
  - Duration
  - Impacts regarding flooding

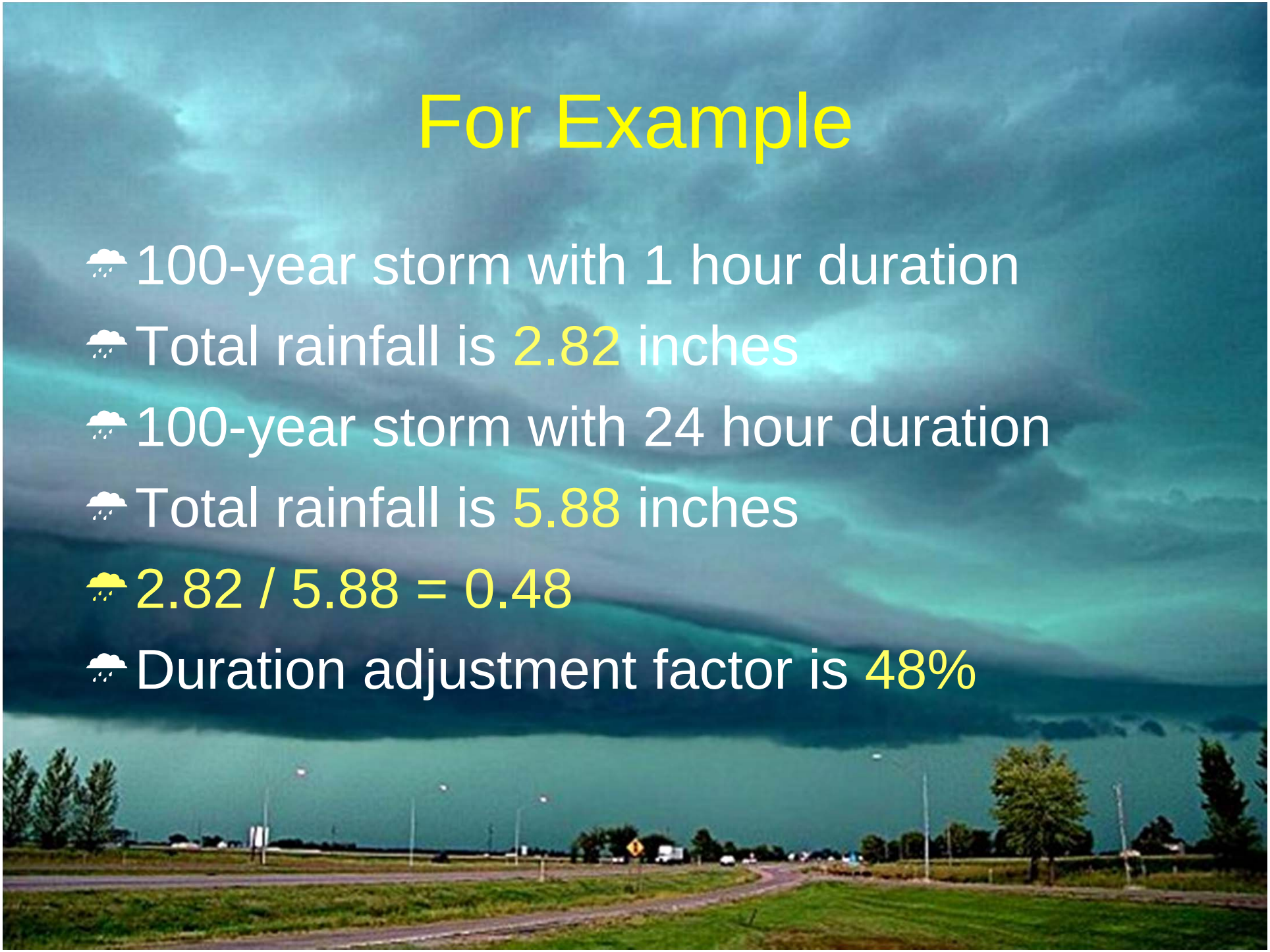


Different Durations of 100-Year Storms Have Different Effects

- 2.8 inches of rain in one hour will wash out roads, culverts, and “flood” streets for a time
- 5.88 inches of rain in 24 hours causes rivers to overtop with widespread flooding

Need to Account for Differences - Duration

- Develop ratio of total rainfall by duration to the 24 hour storm
- Use this ratio to factor up or down the rating of the storm event
- $$\frac{\text{Total rainfall for X duration storm}}{\text{Total rainfall for 24 duration storm}}$$



For Example

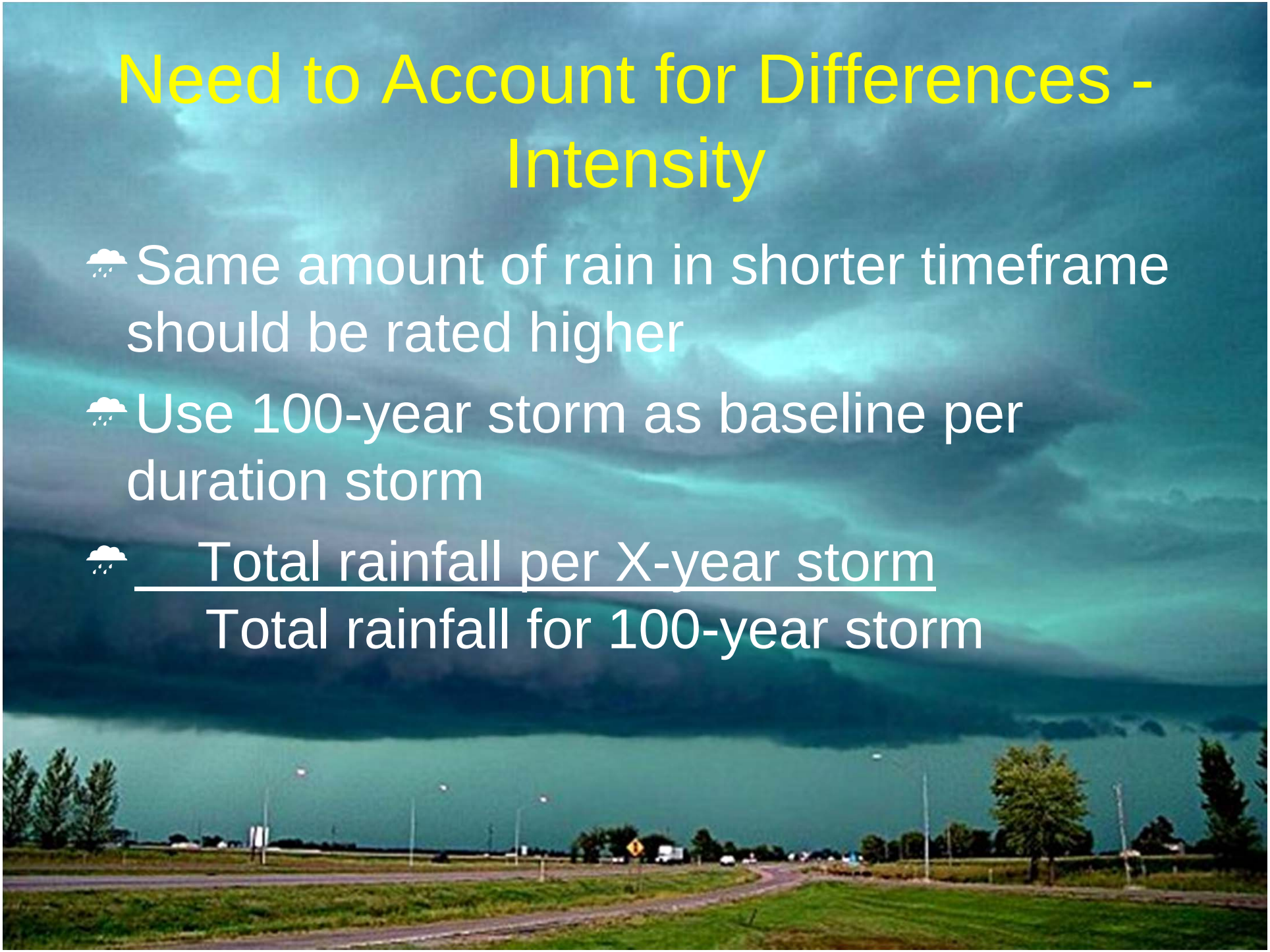
- 100-year storm with 1 hour duration
- Total rainfall is 2.82 inches
- 100-year storm with 24 hour duration
- Total rainfall is 5.88 inches
- 2.82 / 5.88 = 0.48
- Duration adjustment factor is 48%

Duration Adjustment Factors

	Recurrence Interval					
Storm Duration	2 year	5 year	10 year	25 year	50 year	100 year
1 hour	51 %	51 %	51 %	50 %	49 %	48 %
2 hour	60 %	61 %	62 %	62 %	62 %	62 %
3 hour	65 %	66 %	66 %	66 %	66 %	66 %
6 hour	76 %	76 %	77 %	78 %	79 %	80 %
12 hour	87 %	87 %	88 %	88 %	89 %	89 %
24 hour	100 %	100 %	100 %	100 %	100 %	100 %

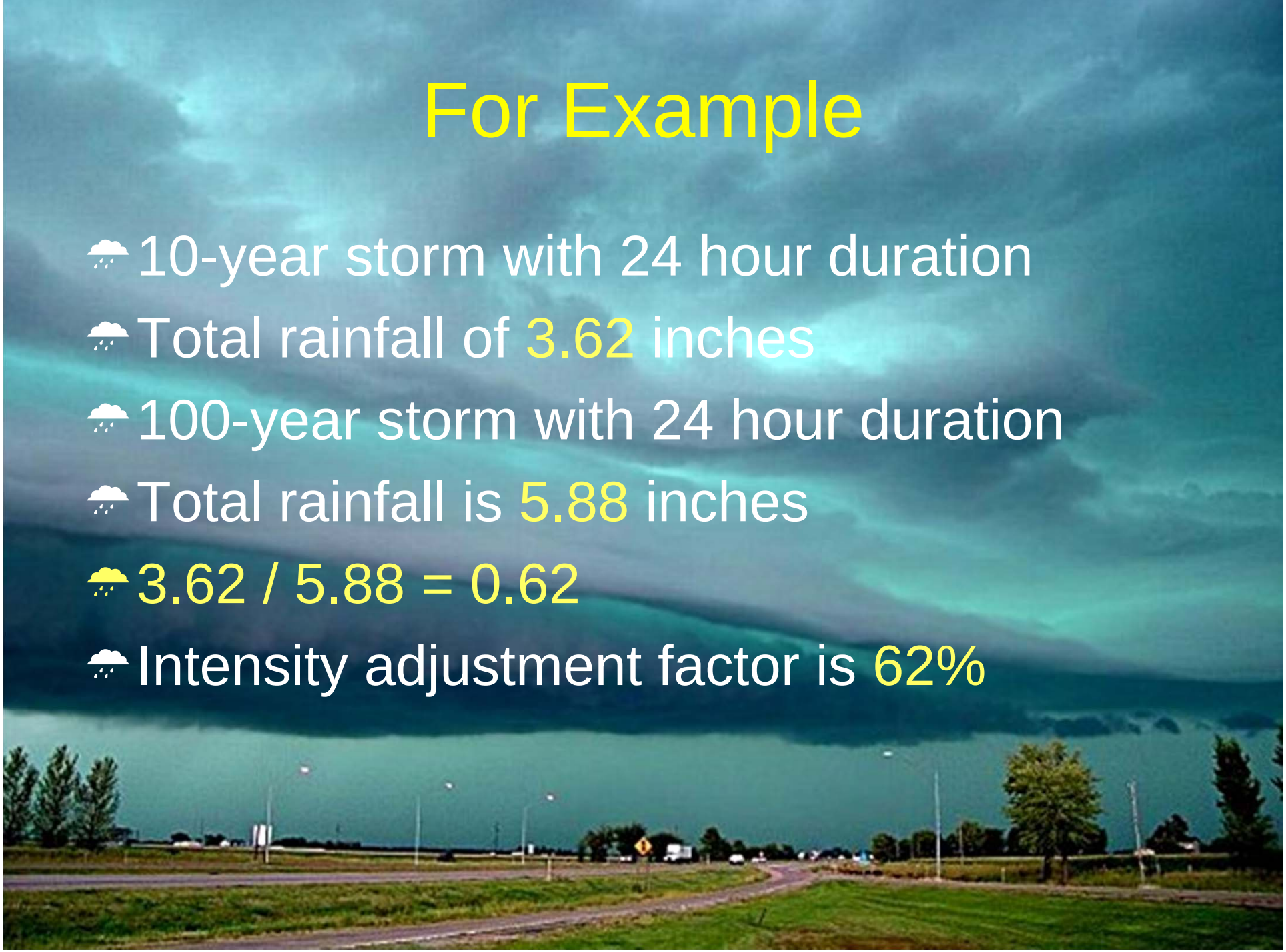
Need to Account for Differences - Intensity

- Same amount of rain in shorter timeframe should be rated higher
- Use 100-year storm as baseline per duration storm
- $\frac{\text{Total rainfall per X-year storm}}{\text{Total rainfall for 100-year storm}}$



For Example

- 10-year storm with 24 hour duration
- Total rainfall of 3.62 inches
- 100-year storm with 24 hour duration
- Total rainfall is 5.88 inches
- 3.62 / 5.88 = 0.62
- Intensity adjustment factor is 62%



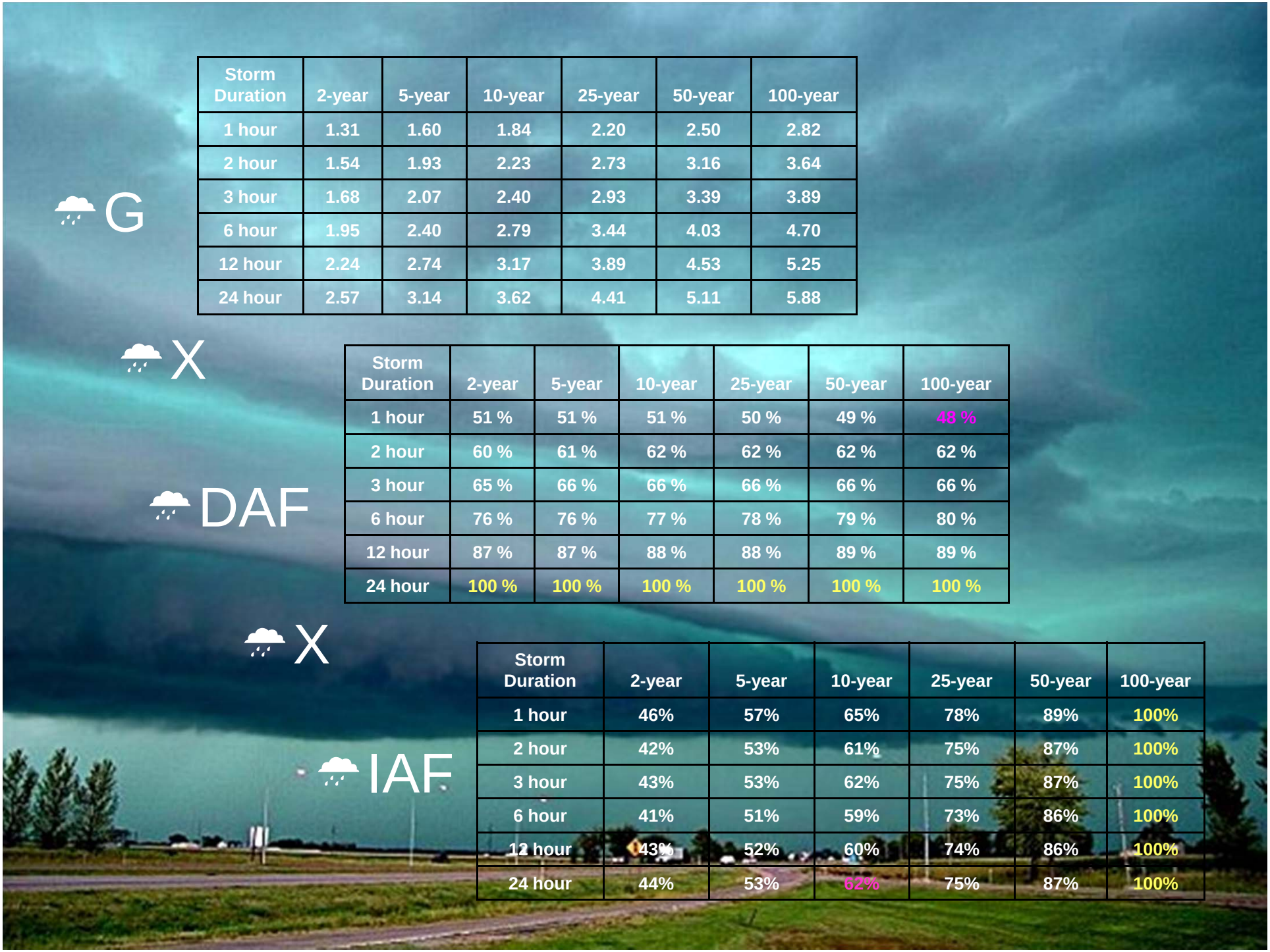
Intensity Adjustment Factors

Recurrence Interval

Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	46%	57%	65%	78%	89%	100%
2 hour	42%	53%	61%	75%	87%	100%
3 hour	43%	53%	62%	75%	87%	100%
6 hour	41%	51%	59%	73%	86%	100%
12 hour	43%	52%	60%	74%	86%	100%
24 hour	44%	53%	62%	75%	87%	100%

Revised Category Storm

- G_{ADJ}={1+Log(RI)/Log(2)} x (DAF) x (IAF)
- G_{ADJ} = the Adjusted Category of storm
- Duration adjustment factor:
  - $\frac{\text{Total rainfall for X duration storm}}{\text{Total rainfall for 24 duration storm}}$
- Intensity adjustment factor:
  - $\frac{\text{Total rainfall per X-year storm}}{\text{Total rainfall for 100-year storm}}$



G

Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	1.31	1.60	1.84	2.20	2.50	2.82
2 hour	1.54	1.93	2.23	2.73	3.16	3.64
3 hour	1.68	2.07	2.40	2.93	3.39	3.89
6 hour	1.95	2.40	2.79	3.44	4.03	4.70
12 hour	2.24	2.74	3.17	3.89	4.53	5.25
24 hour	2.57	3.14	3.62	4.41	5.11	5.88

X

DAF

Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	51 %	51 %	51 %	50 %	49 %	48 %
2 hour	60 %	61 %	62 %	62 %	62 %	62 %
3 hour	65 %	66 %	66 %	66 %	66 %	66 %
6 hour	76 %	76 %	77 %	78 %	79 %	80 %
12 hour	87 %	87 %	88 %	88 %	89 %	89 %
24 hour	100 %	100 %	100 %	100 %	100 %	100 %

X

IAF

Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	46%	57%	65%	78%	89%	100%
2 hour	42%	53%	61%	75%	87%	100%
3 hour	43%	53%	62%	75%	87%	100%
6 hour	41%	51%	59%	73%	86%	100%
12 hour	43%	52%	60%	74%	86%	100%
24 hour	44%	53%	62%	75%	87%	100%

Placing the Recurrence Interval Storm into the New Rating System

	Recurrence Interval					
Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	2	3	4	6	7	8
2 hour	2	3	4	6	7	8
3 hour	2	3	4	6	7	8
6 hour	2	3	4	6	7	8
12 hour	2	3	4	6	7	8
24 hour	2	3	4	6	7	8

Intensity & Duration Adjusted Category Storms

Recurrence Interval

Storm Duration	2 year	5 year	10 year	25 year	50 year	100 year
1 hour	0	1	1	2	3	4
2 hour	1	1	2	3	4	5
3 hour	1	1	2	3	4	5
6 hour	1	1	2	3	4	6
12 hour	1	2	2	4	5	7
24 hour	1	2	3	4	6	8

Existing Rainfall Frequencies and Rainfall Depths for Southeastern Wisconsin

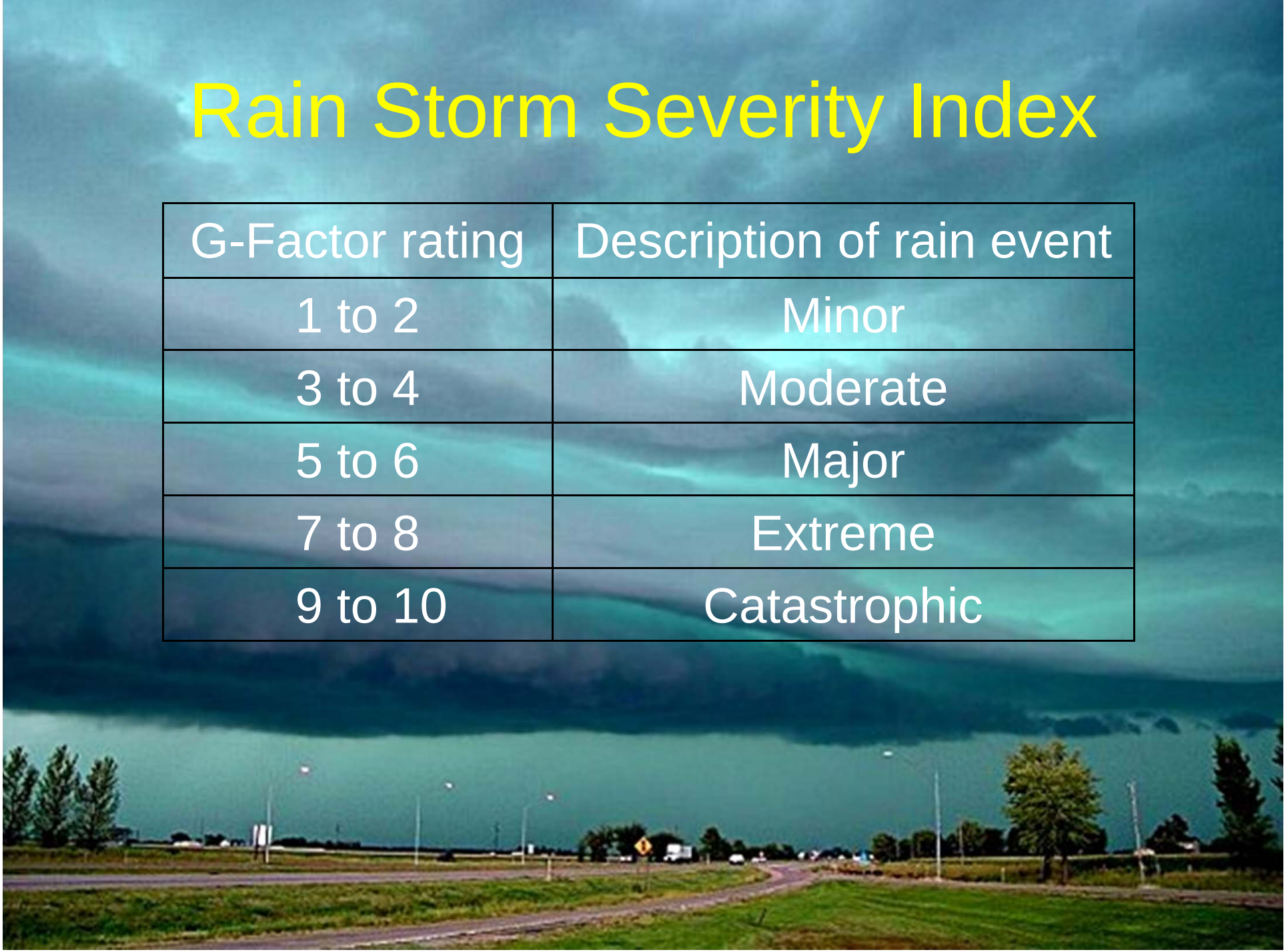
Recurrence Interval and Depth of Rainfall (inches)

Storm Duration	2 year	5 year	10 year	25 year	50 year	100 year
1 hour	1.31”	1.60”	1.84”	2.20”	2.50”	2.82”
2 hour	1.54”	1.93”	2.23”	2.73”	3.16”	3.64”
3 hour	1.68”	2.07”	2.40”	2.93”	3.39”	3.89”
6 hour	1.95”	2.40”	2.79”	3.44”	4.03”	4.70”
12 hour	2.24”	2.74”	3.17”	3.89”	4.53”	5.25”
24 hour	2.57”	3.14”	3.62”	4.41”	5.11”	5.88”

- If rain exceeds these values, interpolate to next higher G-factor

Rain Storm Severity Index

G-Factor rating	Description of rain event
1 to 2	Minor
3 to 4	Moderate
5 to 6	Major
7 to 8	Extreme
9 to 10	Catastrophic



Brookfield Flooding Revisited

- Recent history of flooding in Brookfield
- June 20 - 21, 1997: 6” in 26 hours = G-8
- August 6, 1998: 11.35” in 8 hours = G-10+
- June 7 - 8, 2008: 5.8” in 24 hours = G-8
- June 19, 2009: 4.8+” in 3 hours = G-7
- July 22, 2010: 6.2” in 20 hours = G-9
- No implication of rarity!!!

Las Vegas, Nevada

Total rainfall (inches)

Storm Duration	Recurrence Interval					
	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	0.51	0.73	0.92	1.18	1.40	1.65
2 hour	0.62	0.87	1.09	1.41	1.70	2.02
3 hour	0.69	0.95	1.18	1.50	1.78	2.09
6 hour	0.83	1.15	1.41	1.77	2.07	2.41
12 hour	0.98	1.36	1.64	2.04	2.36	2.70
24 hour	1.10	1.50	1.80	2.21	2.51	2.83
2 day	1.18	1.61	1.93	2.35	2.68	3.01
4 day	1.60	1.78	2.14	2.60	2.94	3.29
7 day	1.46	2.01	2.39	2.88	3.24	3.60
10 day	1.58	2.17	2.58	3.09	3.47	3.83

- Source: NOAA website

Las Vegas, Nevada

Storm Duration	Recurrence Interval					
	2 year	5 year	10 year	25 year	50 year	100 year
1 hour	0	1	1	2	3	4
2 hour	0	1	1	3	4	5
3 hour	0	1	2	3	4	6
6 hour	1	1	2	3	5	7
12 hour	1	1	2	4	5	7
24 hour	1	2	3	4	6	8

Washington D.C.

Total rainfall (inches)

Recurrence Interval

Storm Duration	2-year	5-year	10-year	25-year	50-year	100-year
1 hour	1.47	1.85	2.14	2.53	2.84	3.15
2 hour	1.71	2.17	2.52	3.02	3.42	3.85
3 hour	1.83	2.32	2.71	3.27	3.73	4.21
6 hour	2.24	2.83	3.32	4.03	4.64	5.31
12 hour	2.70	3.44	4.07	5.03	5.87	6.80
24 hour	3.15	4.05	4.84	6.05	7.13	8.35
2 day	3.66	4.69	5.57	6.91	8.07	9.37
4 day	4.06	5.19	6.17	7.62	8.89	10.30
7 day	4.69	5.93	6.99	8.58	9.94	11.45
10 day	5.34	6.67	7.78	9.40	10.76	12.23

- Source: NOAA website

Washington D.C.

Recurrence Interval

Storm Duration	2 year	5 year	10 year	25 year	50 year	100 year
1 hour	0	1	1	2	2	3
2 hour	0	1	1	2	3	4
3 hour	1	1	2	2	3	4
6 hour	1	1	2	3	4	5
12 hour	1	1	2	3	5	6
24 hour	1	2	3	4	6	8

Criticism and Scrutiny

- No continuous curve for each category storm
- Interpret between durations to pick the right category storm
- Or develop a look-up table or formula to interpolate (any interns available for a unique project?)

Criticism and Scrutiny

- Does not address:
  - antecedent moisture,
  - snowmelt,
  - soil types,
  - % of impervious cover,
  - etc.
- Not intended to!
- These relate to runoff, not the rain storm event

Criticism and Scrutiny

- Just another name for the 100-year storm
- Precisely. That's the point!
- Better way to communicate to public
- Severity, not rarity, is key to public's understanding

Advantages of a New System

- Preserves the existing data and science
- Does not require overhaul of hydrology or engineering
- Generally consistent with rating systems for other natural disasters
- Easy to understand
- Bigger the number, the bigger the storm

Advantages of a New System

- Provides a more appropriate scaling factor
  - The 50-year storm is not 50% as big as the 100-year storm as some might assume
  - It is almost as big (Typically only 1 unit away)
- Uses different terminology than for floodplains
- Avoids confusion that 100-year storm always results in the 100-year flood
- Or that the 100-year flood can only occur when there's a 100-year storm

Advantages of a New System

- Does not imply that big storms are rare
- Minimizes criticism, skepticism and general disregard for hydrologic or engineering descriptions of the event
- Makes it clear to people that these are big storms that we should take seriously
- Incents people to protect themselves against larger event

Pitching this Idea to the Nation

- Presented to numerous professional societies:
  - WAFSCM, WI APWA, SE WI ASCE
  - Central States WEA
  - ASFPM national conference
  - NWS - ER Flash Flood conference
- Lots of encouragement
- Follow-up with NWS DC office

2010 National Weather Service Strategic Plan Comments

- Added comment that we should re-label extreme rainfall events so the public understands their severity
- Second most agreed with comment on the website: 166 people agreed
- Thanks for those who agreed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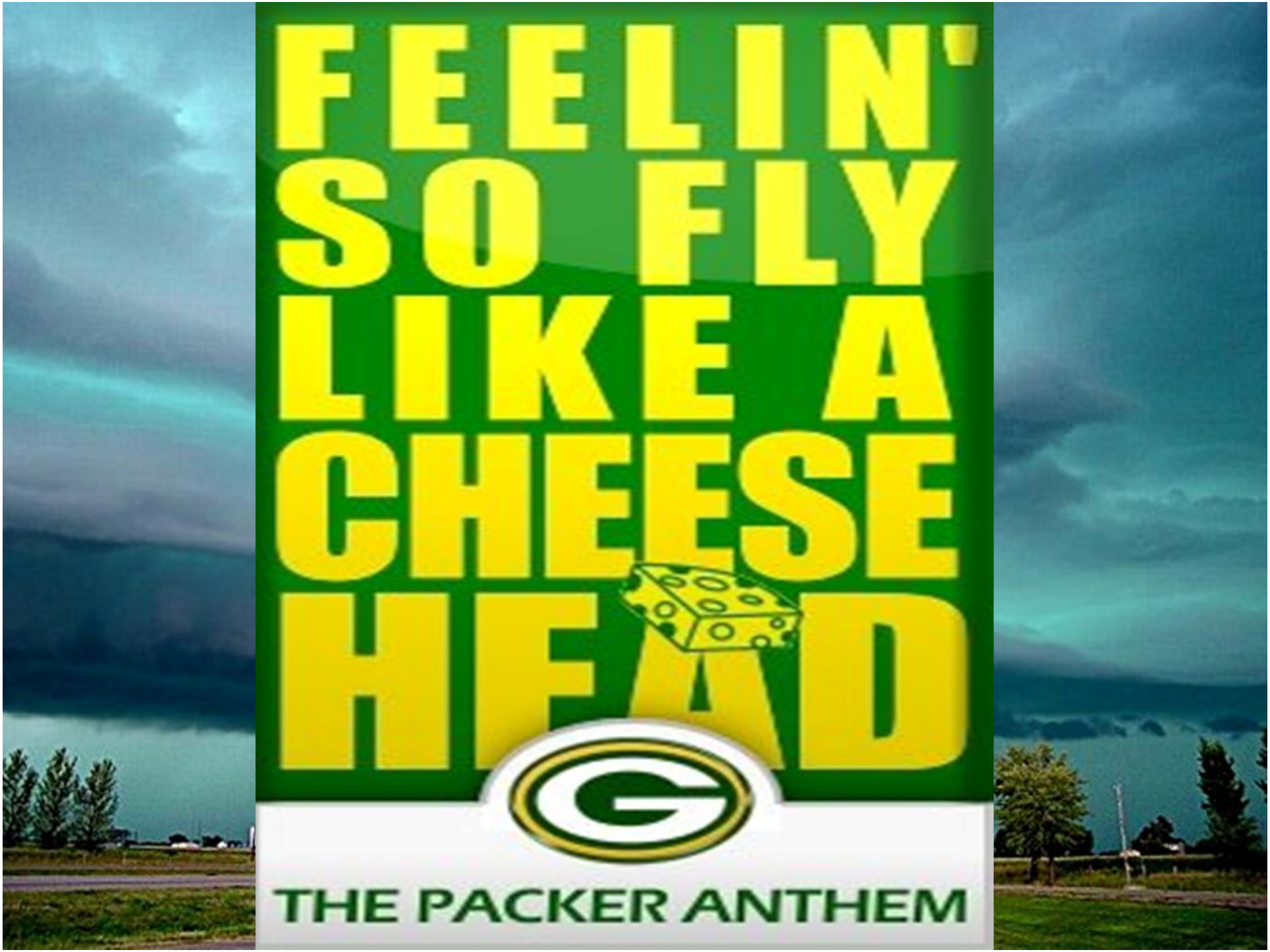
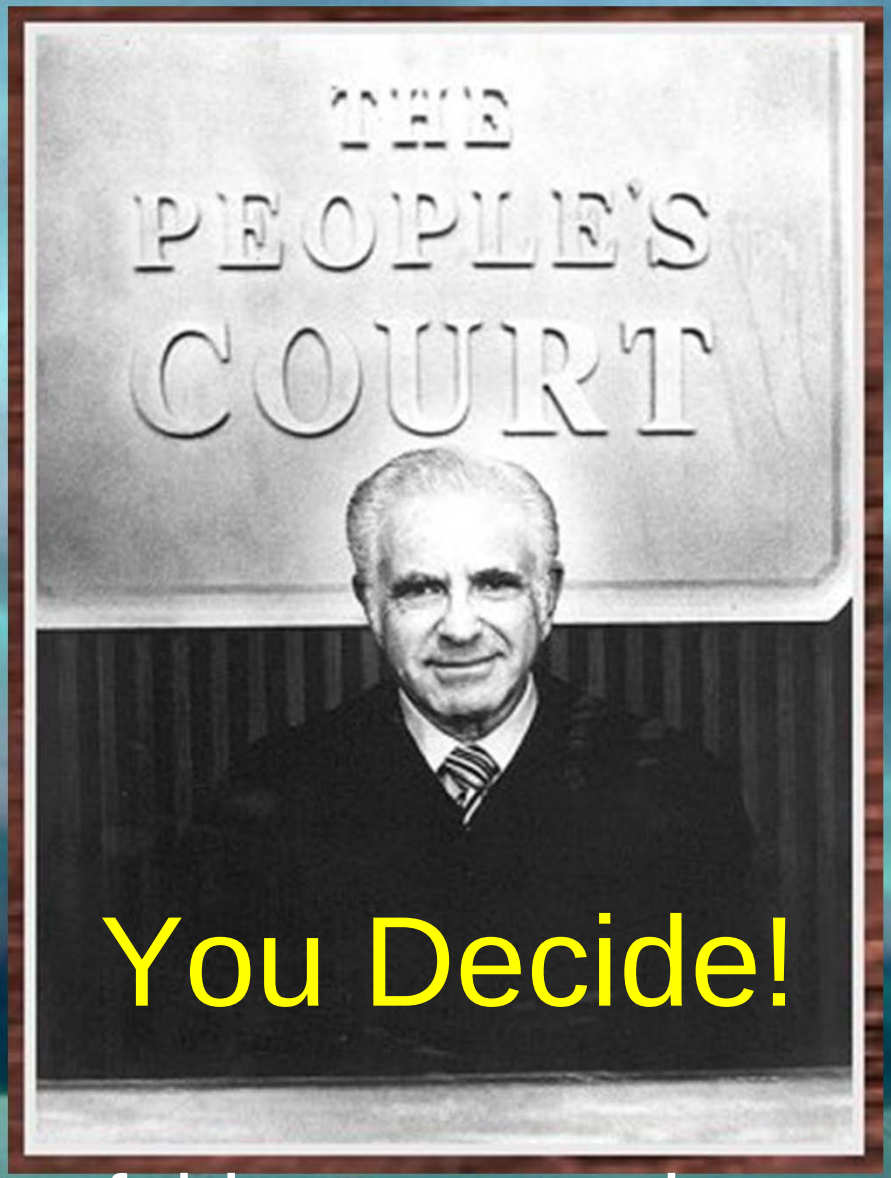

FEELIN'
SO FLY
LIKE A
CHEESE
HEAD
THE PACKER ANTHEM

Does This Make Sense?



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