The Coming Hurricanes, Sea Level Rise & Effects On Community Trees

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STORM HISTORY

Property & Lives – Georgia's Devastating 1750-1900 Storms

1752 "The Great Hurricane" cat. 3

1804 Savannah cat. 3

1813 St. Mary's cat. 3

(catastrophic damage -- St.Mary's & sea islands -- 19 ft surge)

1824 Darien

1854 Darien cat. 3 (slow moving)

1881 St. Catherine's cat. 2

("Georgia Hurricane" -- 10th deadliest in US – 15ft surge)

1893 Wassaw Island cat. 3

("Sea Islands Hurricane" -- 6ft water covered Tybee – 7th deadliest in US – 16-30 ft surge)

1896 tropical storm

(108mph on Tybee – "Brunswick wrecked")

1898 Cumberland Island cat. 4

(16ft surge on island & along coast – strongest on record -- "Georgia's tidal wave")

Fraser 2006

Georgia Storms 1901-2001

Fraser 2006 & NOAA

1911 -- tropical storm

1928 San Felipe / Okeechobee cat. 4

1947 -- tropical storm

(75-110 mph – 12 ft surge at Tybee)

1964 Dora – Darien cat. 2

(slow moving – pounds St. Simons & Brunswick)

1979 David – Ossabaw cat. 1

1989 Hugo – Georgetown, SC cat. 4

1994 Alberto (27” rain Americus)

1995 Opal cat. 3 (70mph winds NW Ga)

2001 Allison (winds & rain along fall line

Multiple Storms – Atlantic & Gulf

(coast & inland battered by tornado strings & torrential rains -- 15-28" rain from residual)

1750 - 2016

Georgia Coast

12 hurricanes

(2 cat. 4 & 6 cat. 3)

+ 39 major tropical storms

Georgia State

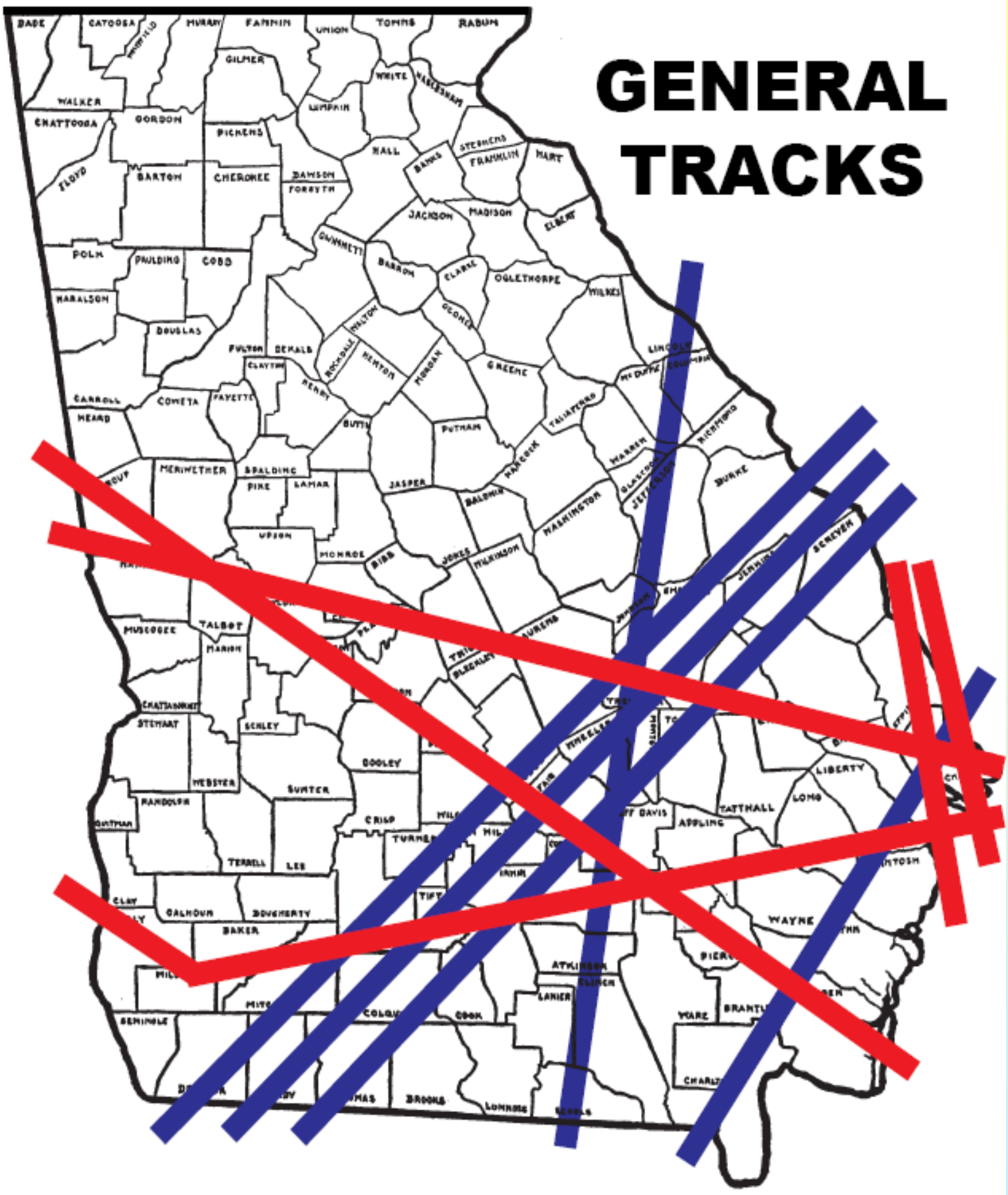
26 hurricane impacts

in recorded history

(definition problem with tropical storms)

Fraser 2006

HURRICANE TRACKS (CAT. 1-5)



HURRICANE

! ! ! ! !

Modified Saffir-Simpson Hurricane Wind Scale

(NOAA 2012)

cat. 1 – 74-95mph

cat. 2 – 96-110mph

cat. 3 – 111-129mph

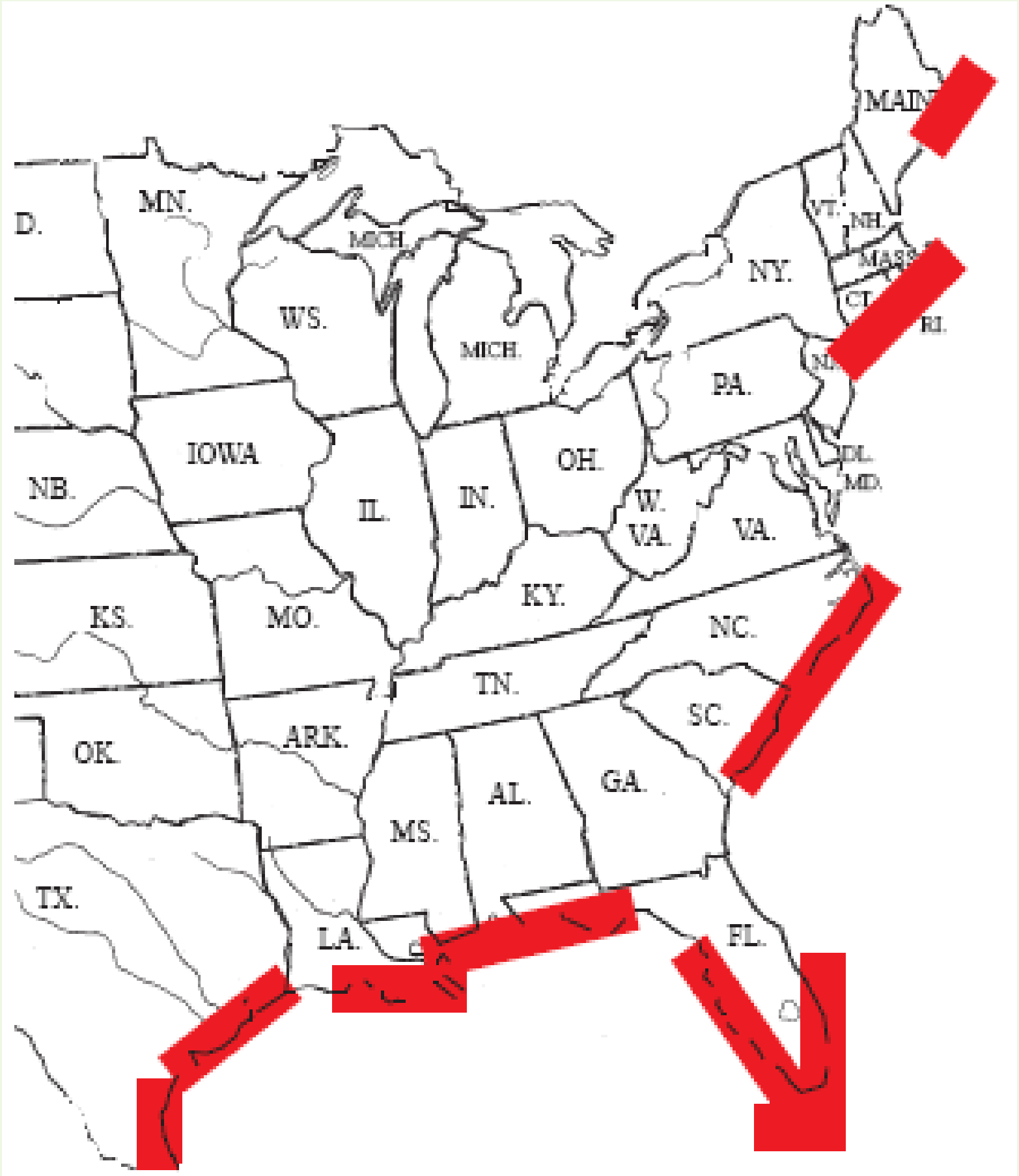
cat. 4 – 130-156mph

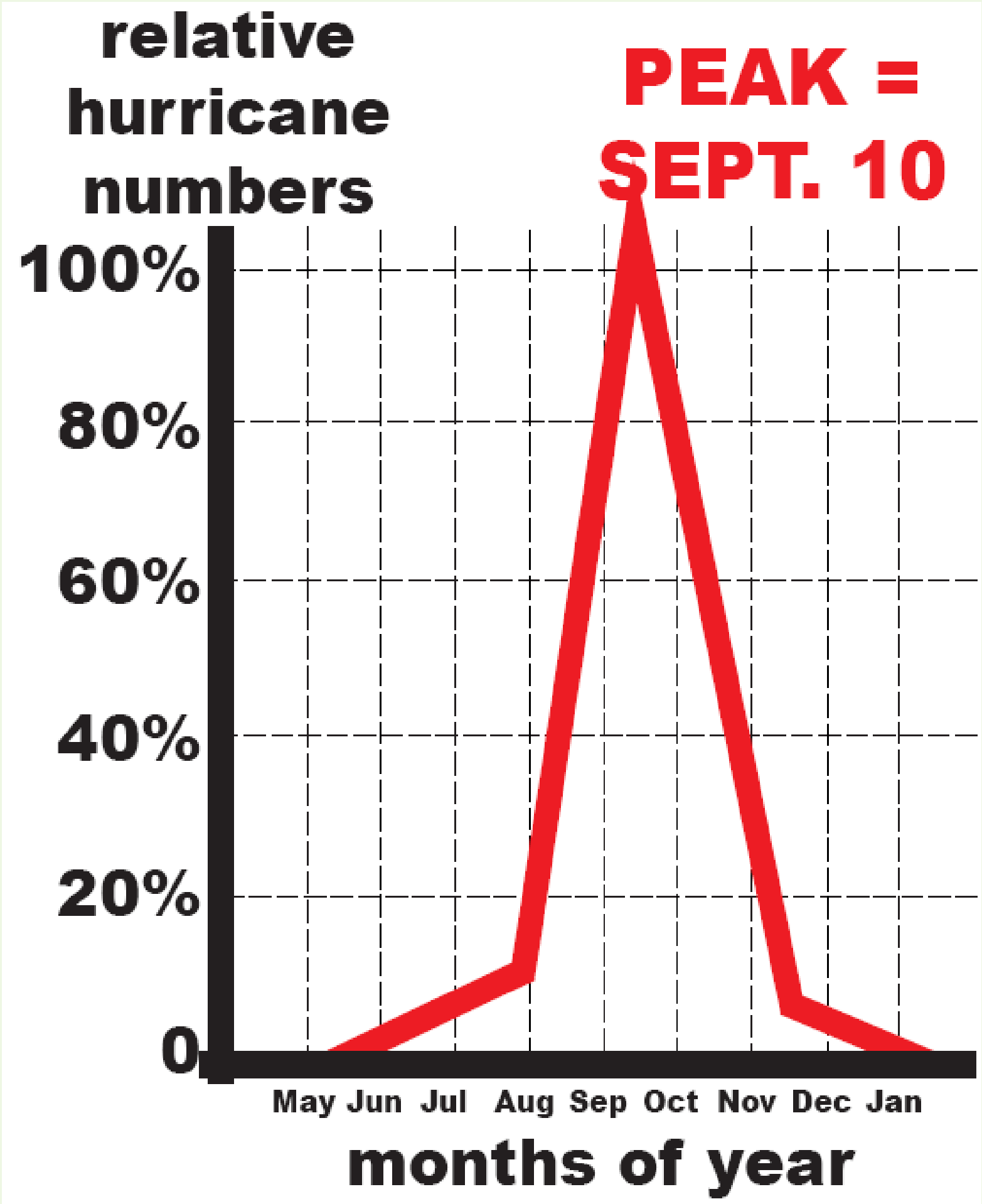
cat. 5 – >157mph

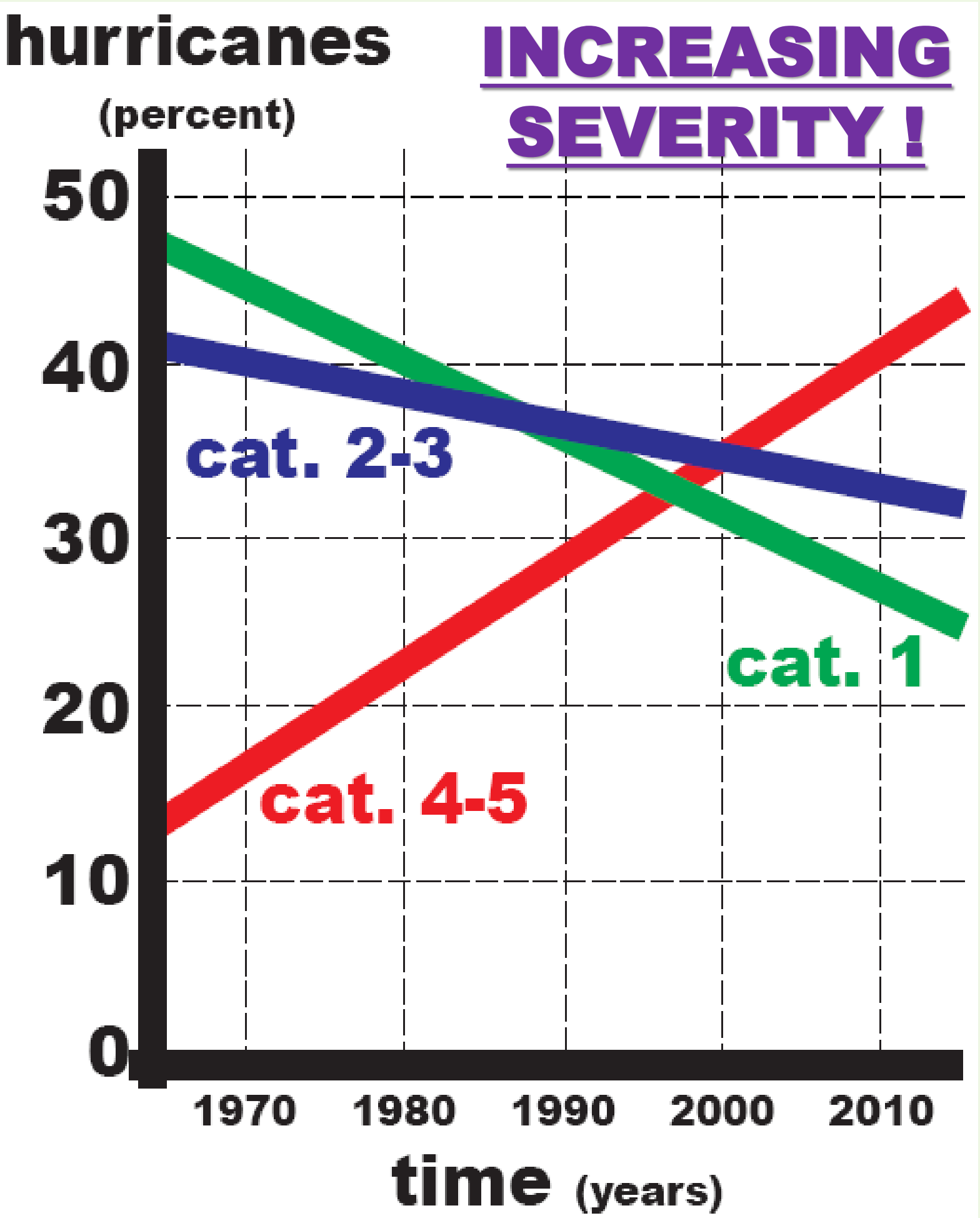
-- sustained wind speed --

cat. 3-5 = major hurricanes

Hurricane Landfalls Over 50 Years




relative hurricane numbers
PEAK = SEPT. 10
100%
80%
60%
40%
20%
0
May Jun Jul Aug Sep Oct Nov Dec Jan
months of year


hurricanes
(percent)
INCREASING SEVERITY !
50
40
30
20
10
0
cat. 2-3
cat. 1
cat. 4-5
1970
1980
1990
2000
2010
time (years)

CHANCES

all Atlantic hurricanes

40% hit FL

16% hit NC

7% hit GA

(14.3 years)

Sustained ~60 mph Winds For Cat. 3 Landfall

Savannah

(120 years since last)

84 years over-due

Brunswick

(125 years since last)

91 years over-due

HURRICANE INTENSITY

increased over last 30 years

FUTURE: not more, but more intense

larger peak winds
more heavy rains
more energy

Williams et.al. 2009

Future Hurricanes

(9°F warmer / 2016-2035)

+11% cat. 3-5 storms

+3.6X cat. 5+

+6% intense winds

(& faster storm spin-up)

20% slower movement

+24% more rainfall

(larger storms over one spot longer with more wind & rain)

NOAA – Nature, 2018; NCAR – Journal of Climate, 2018
Williams et.al. 2009

STORM SURGE

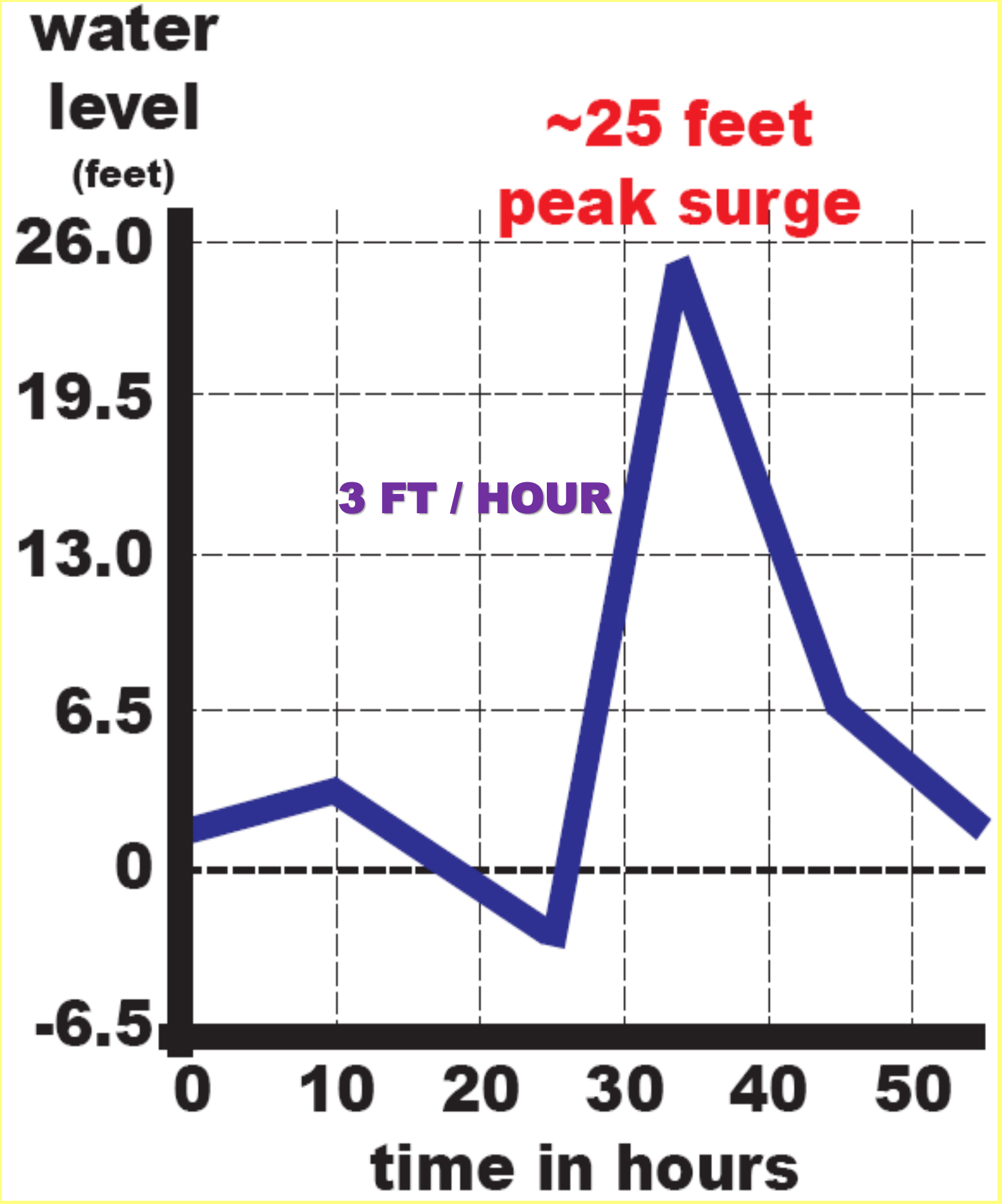
Storm Surge

wind push (85%)
wave push (7.5%)
eye pressure (7.5%)

Surge Waters

NOT wall, but rapid (minutes) rise of water

current same as class 3-5 white water rapids



CAMILLE -- CAT. 5 -- 1969 -- MISSISSIPPI

Selected Hurricane Surge Levels

Sandy	2012	13 ft
Katrina	2005	27 ft
Dennis	2005	8 ft
Isabel	2003	8 ft
Opal	1995	24 ft
Hugo	1989	20 ft
Camille	1969	24 ft
Audrey	1957	12 ft

Pilkey et.al. 2016

Components Of Visible High Water Marks

Surge
High Tide
Wave Height

EXAMPLE:
15ft + 2ft + 10ft =
27ft total height

1990 – 2008

Population Vulnerability

to storm surge increased 17% along Atlantic Coast counties

(NOAA data)

GEORGIA COAST

number of properties at storm surge risk = 118,000

Pilkey et.al. 2016

EXPECTATIONS

Coastal property values decline quick over next 40 years.

Shoreline shifts quick over next 80 years.

Sea level rise for at least next 250 years.

Englander 2014

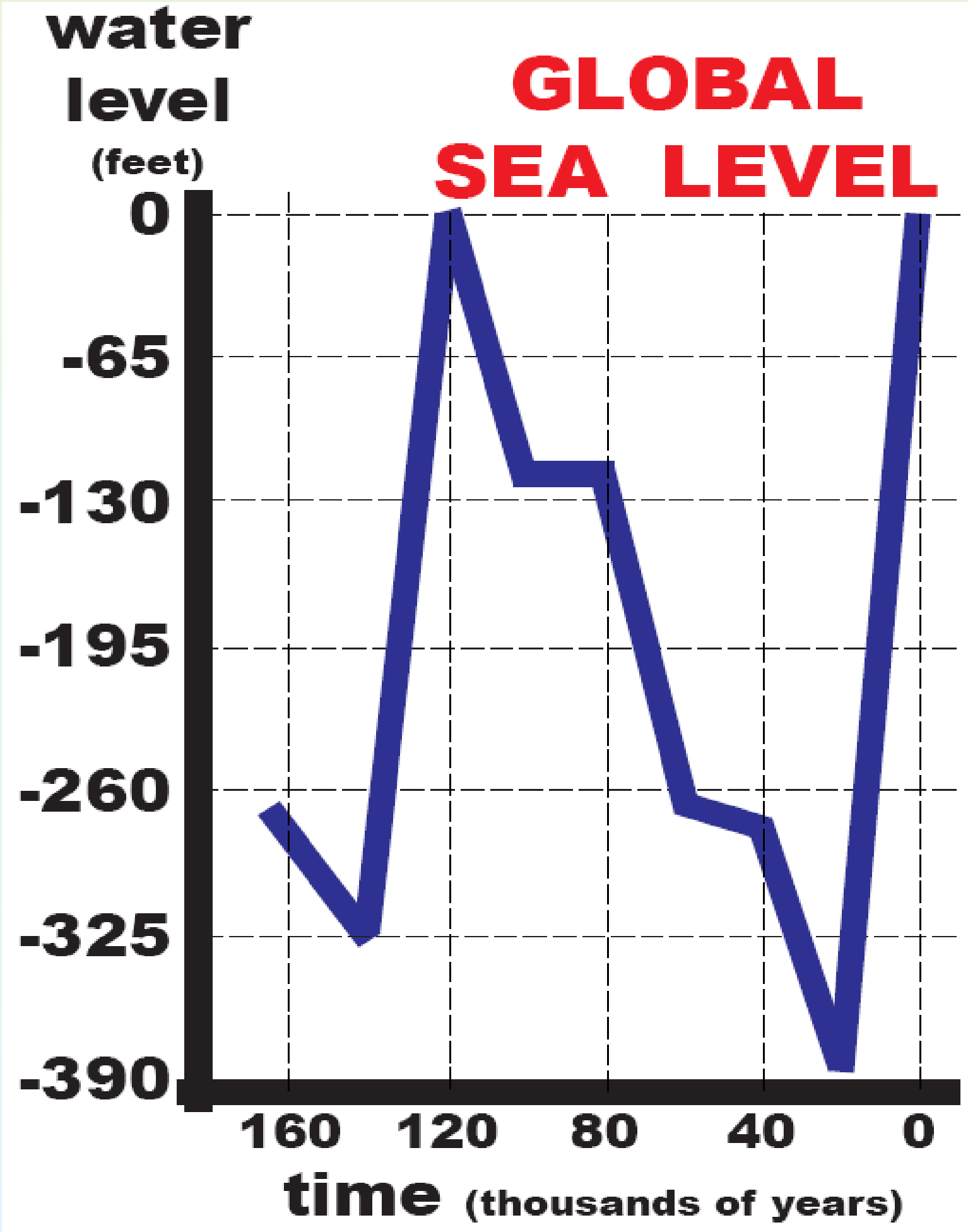
SEA LEVEL RISE

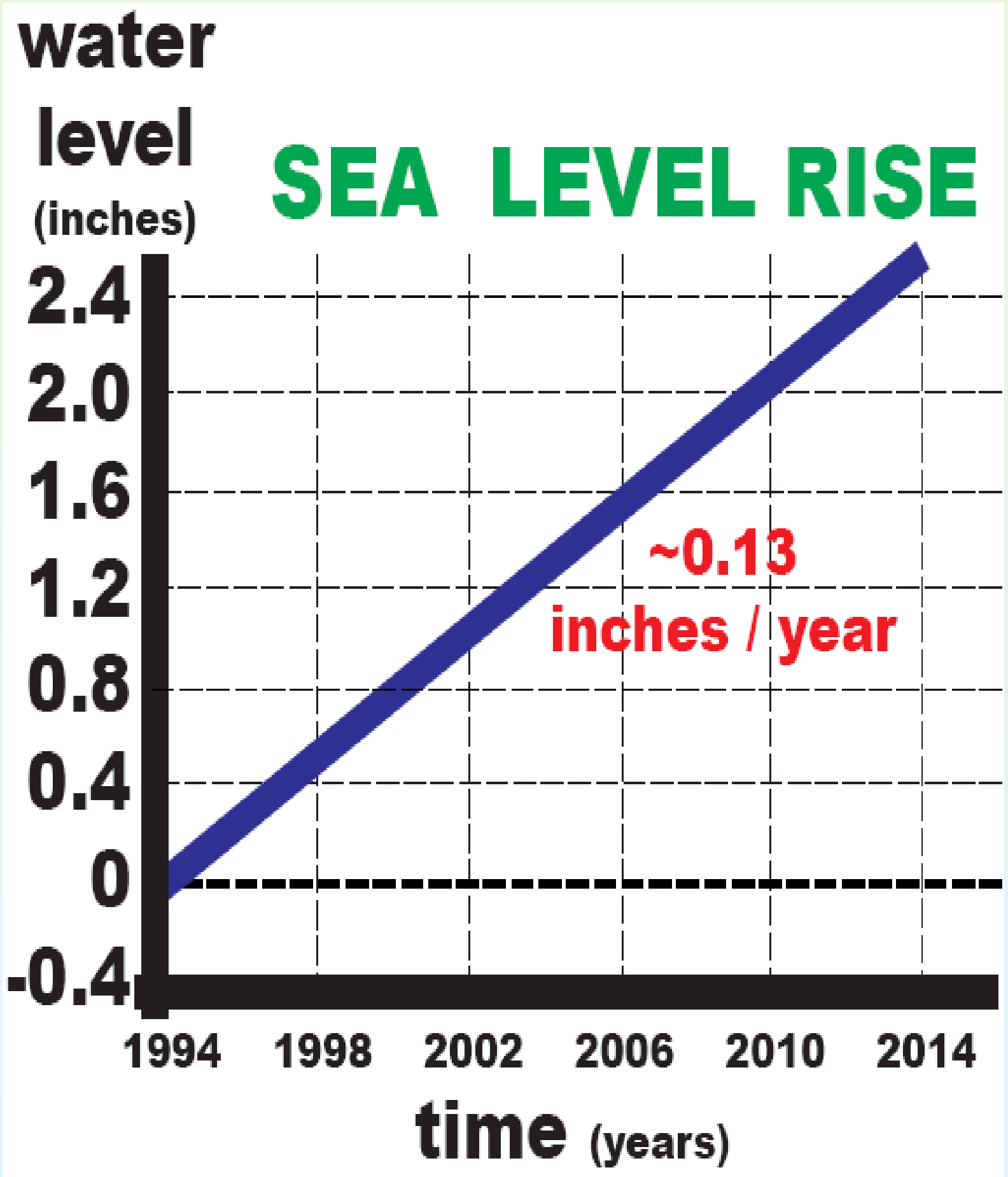
Last 15,000 yrs sea level rise = ~380ft

Last 540 myrs sea level change = ~1,200 ft

(775 ft higher / 460 ft lower)

Hine et.al. 2016


water level (feet)
GLOBAL SEA LEVEL
0
-65
-130
-195
-260
-325
-390
160
120
80
40
0
time (thousands of years)


water level (inches)
SEA LEVEL RISE
2.4
2.0
1.6
1.2
0.8
0.4
0
-0.4
~0.13 inches / year
1994
1998
2002
2006
2010
2014
time (years)

EXAMPLE:

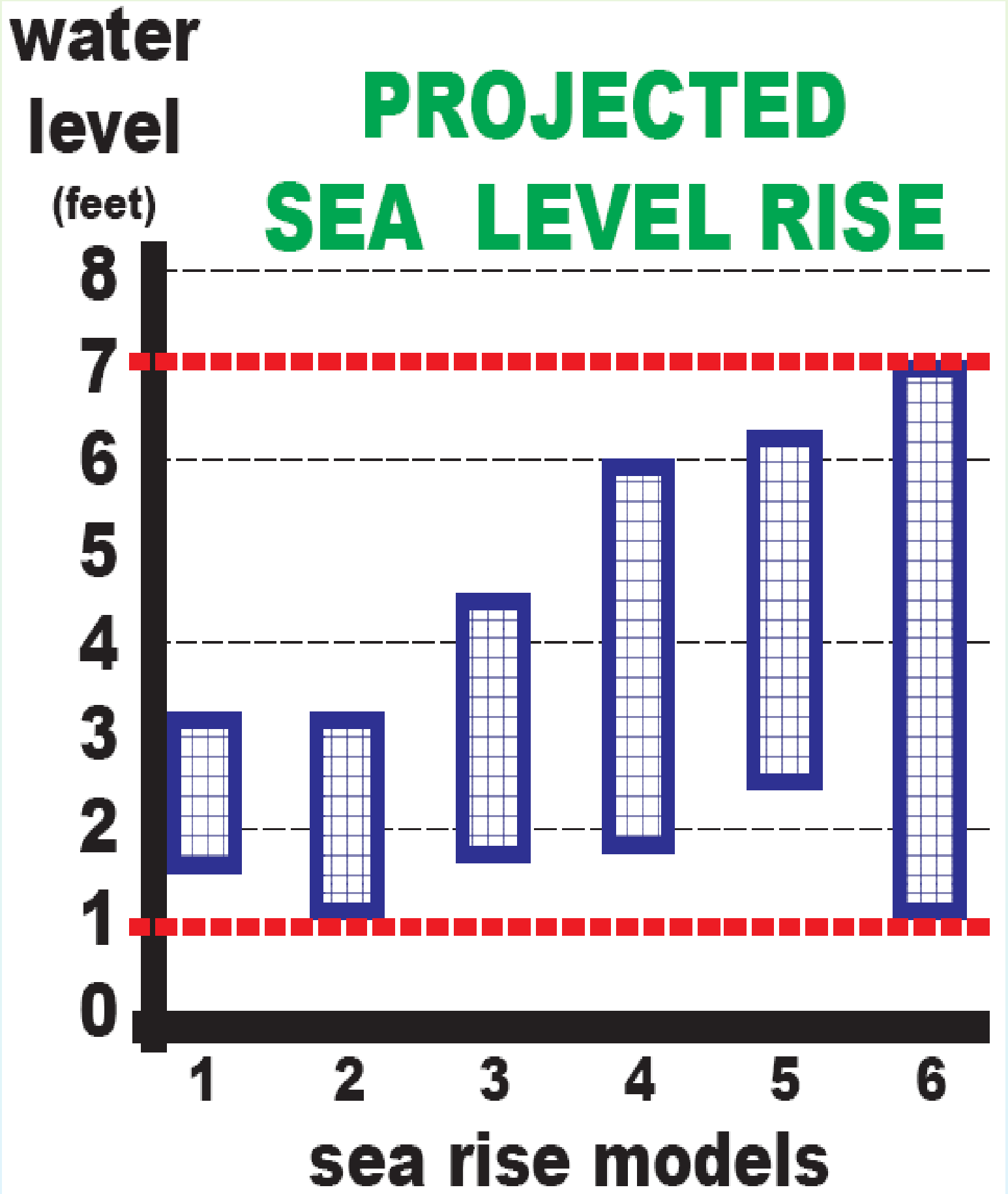
Ft. Pulaski, GA

daily tidal range = 4.3 - 9.8 feet

Conrads et.al. 2013

current sea level rise = 0.12 in. / year

Conrads et.al. 2013 Williams et.al. 2009


water level (feet)
PROJECTED SEA LEVEL RISE
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
sea rise models

SEA LEVEL RISE PROJECTIONS

St. Simons, GA

Population with homes at risk = 22.9%

Livable land area under water:

--by 2060 = 26.4% --by 2100 = 60.1%

Property value risk 2060 = $1.75 billion

Tybee Island / Wilmington Island, GA

Population with homes at risk = 17.4%

Livable land area under water:

--by 2060 = 32.9% --by 2100 = 70.4%

Property value risk 2060 = $915 million

Union of Concerned Scientists

Sea Level Rise

-more intense storms

-more flooding

-freshwater / seawater inundation

-higher waves

-coastal erosion of barrier islands

-beach sand dunes move landward

Hine et.al. 2016

FLOODING
Freshwater
&
Seawater

Soil Oxygen Content

--tree root growth slowed / hampered below 10%

--tree root growth stops below 5%

–root rots effective 3-5%

Hodson & Bryant 2012; Willey 2016

Anaerobic Soil

can occur within one day at 70°F

Hodson & Bryant 2012; Willey 2016

FLOODING
(freshwater or seawater)
SOIL PORES

-poor soil aeration
(warm water = O2 used in <3 hours)

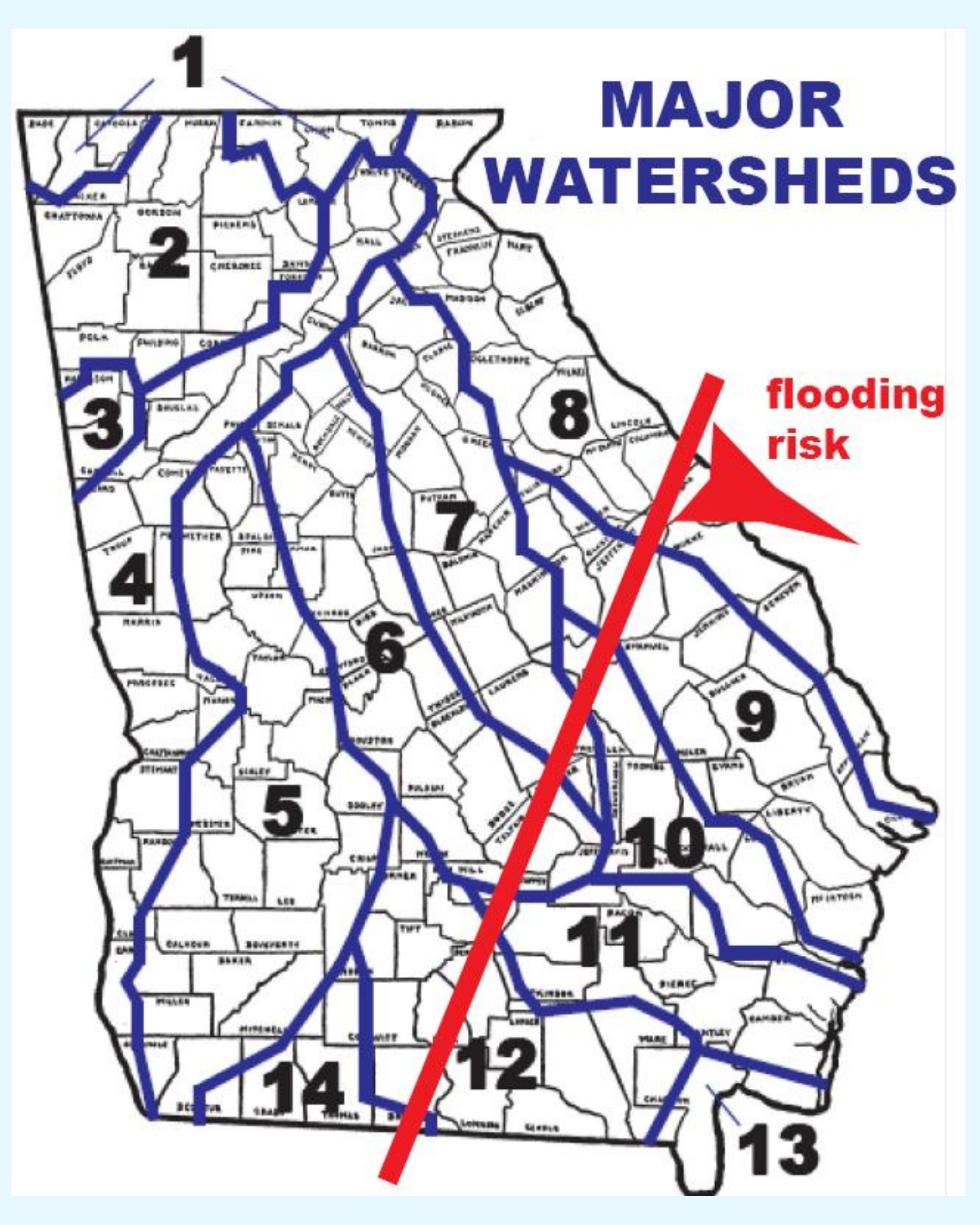
-soil structure destruction

-anaerobic ecology

-reduced chemical & biological activity

-root growth loss
(within 7 days)

Hodson & Bryant 2012; Willey 2016


MAJOR
WATERSHEDS
flooding
risk
1
2
3
4
5
6
7
8
9
10
11
12
13
14

GEORGIA WATERSHEDS AT RISK -- FLOODING

(Atlantic Coast)

Savannah

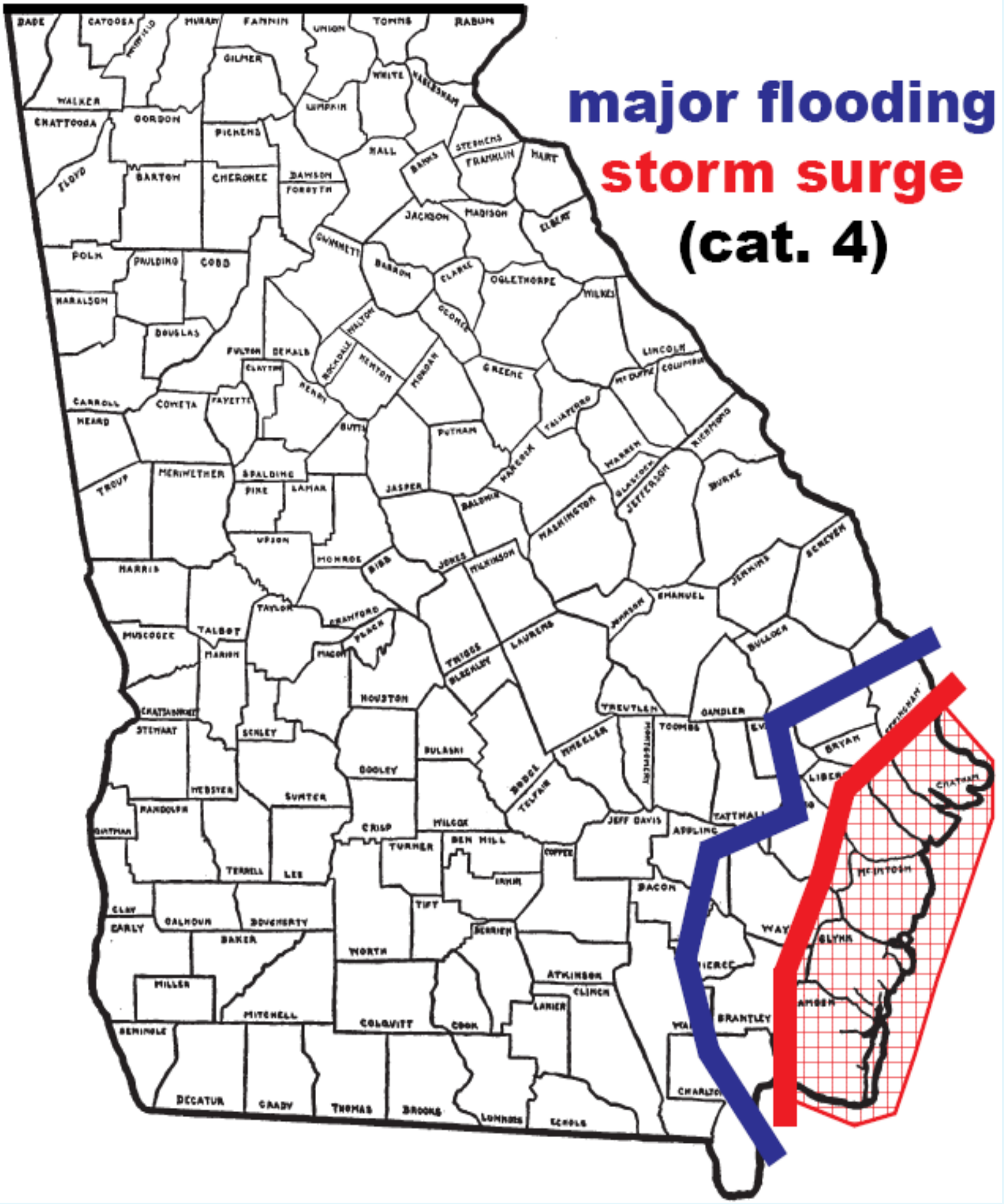
Ogeechee

Altamaha

Satilla

Suwannee

St. Mary


major flooding
storm surge
(cat. 4)
DADE
CATOOSA
WALKER
CHATTOOGA
GORDON
FLOYD
BARTON
CHEROKEE
PICKENS
GILMER
FANNIN
MURRAY
WHITFIELD
UNION
TOWNS
RABUN
WHITE
HABERSHAM
LUMPKIN
DAWSON
FORSYTH
HALL
BANKS
STEPHENS
FRANKLIN
HART
JACKSON
MADISON
ELBERT
GWINNETT
BARROW
CLARKE
OGLETHORPE
WILKES
POLK
PAULDING
COBB
HARALSON
DOUGLAS
FULTON
DEKALB
ROCKDALE
NEWTON
MORGAN
GREENE
LINCOLN
WILKINSON
TALIAFERRO
CARROLL
COWETA
FAYETTE
CLAYTON
HENRY
BUTTS
PUTNAM
HEARD
TROUP
MERIWETHER
SPALDING
PIKE
LAMAR
JASPER
HARRIS
UPSON
MONROE
BIBB
JONES
TALBOT
MUSCOGEE
MARION
TAYLOR
CRAWFORD
PEACH
MACON
HOUSTON
CHATTAHOOCHEE
STEWART
SCHLEY
WEBSTER
SUMTER
RANDOLPH
TERRELL
LEE
CRISP
DOOLEY
BULLOCH
CLAY
CALHOUN
DOUGHERTY
EARLY
BAKER
MILLER
MITCHELL
SEMINOLE
DECATUR
GRADY
THOMAS
BROOKS
LOWNDES
ECHOLS
COLQUITT
COOK
BERRIEN
TIFT
TURNER
WORTH
IRWIN
BEN HILL
WILCOX
WHEELER
TELFAIR
WILKINSON
JOHNSON
EMANUEL
LAURENS
TREUTLEN
TOOMBS
MONTGOMERY
JEFF DAVIS
APPLING
COFFEE
BACON
ATKINSON
CLINCH
LANIER
JENKINS
SCREVEN
BURKE
RICHMOND
WARREN
GLASCOCK
JEFFERSON
WASHINGTON
HANCOCK
BALDWIN
GANDLER
BRYAN
LIBERTY
CHATHAM
MCINTOSH
GLYNN
WAYNE
BRANTLEY
CHARLTON

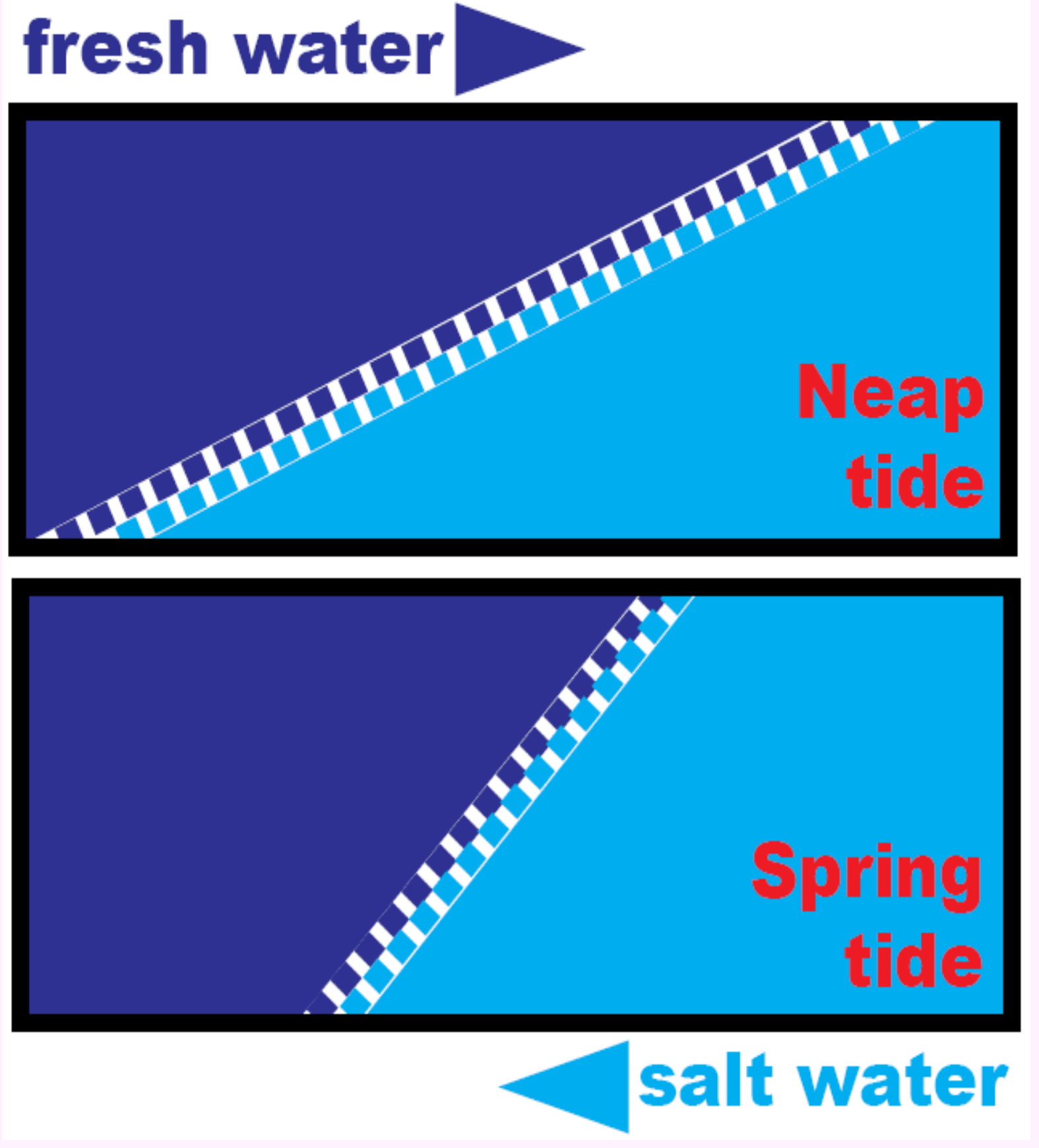
SALT WATER INTRUSION

seawater ~2.7% heavier than freshwater

seawater ~70X more salts than freshwater

seawater pH 7.5 - 8.4

SALTWATER / FRESHWATER INTERFACE IN ESTUARINE RIVERS



SALTWATER / FRESHWATER INTERFACE

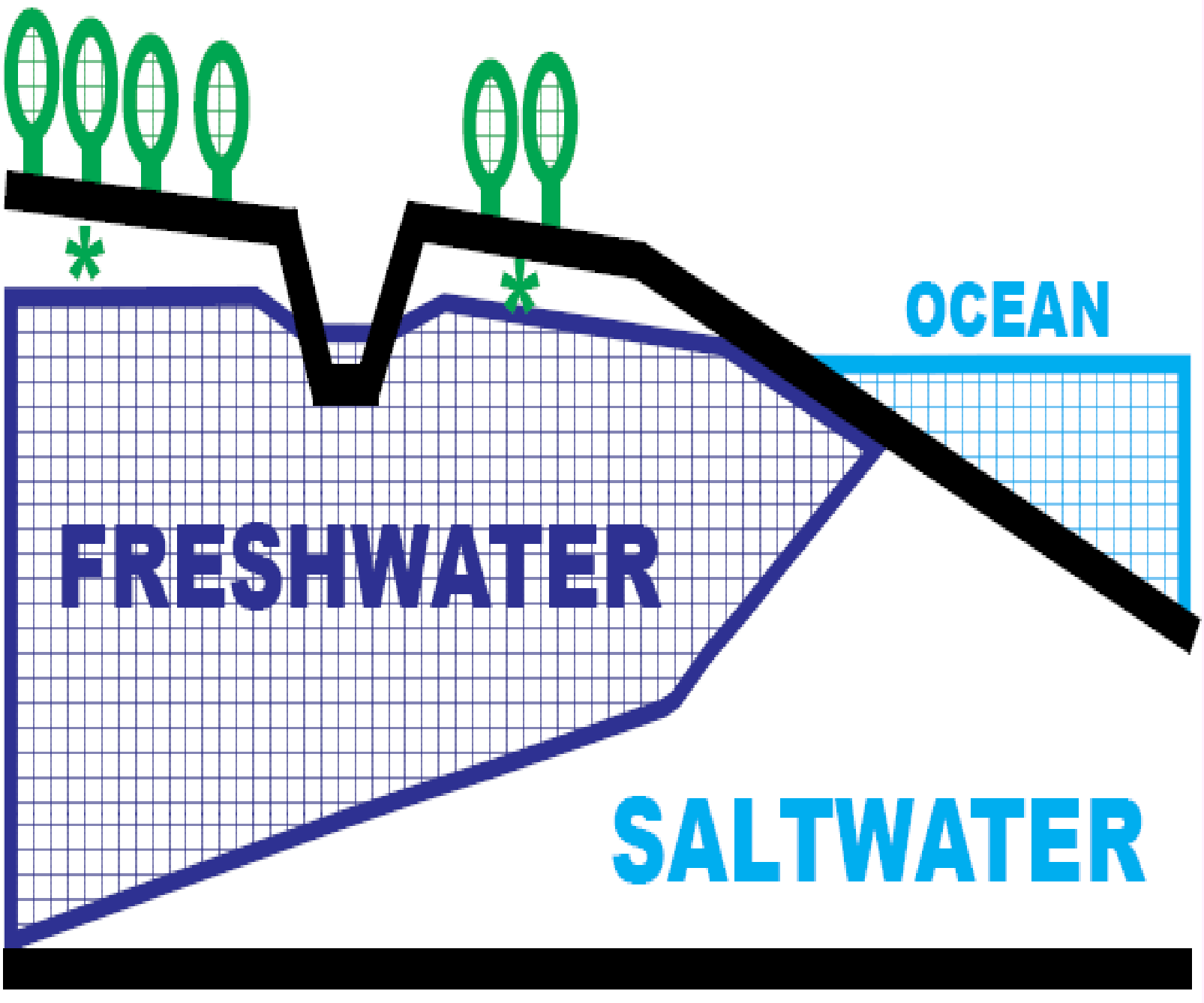
high streamflow –
interface moves downstream

low streamflow –
interface moves upstream

interface upstream:
tidal forcing, sea level rise, & high tide range

Conrads et.al. 2013

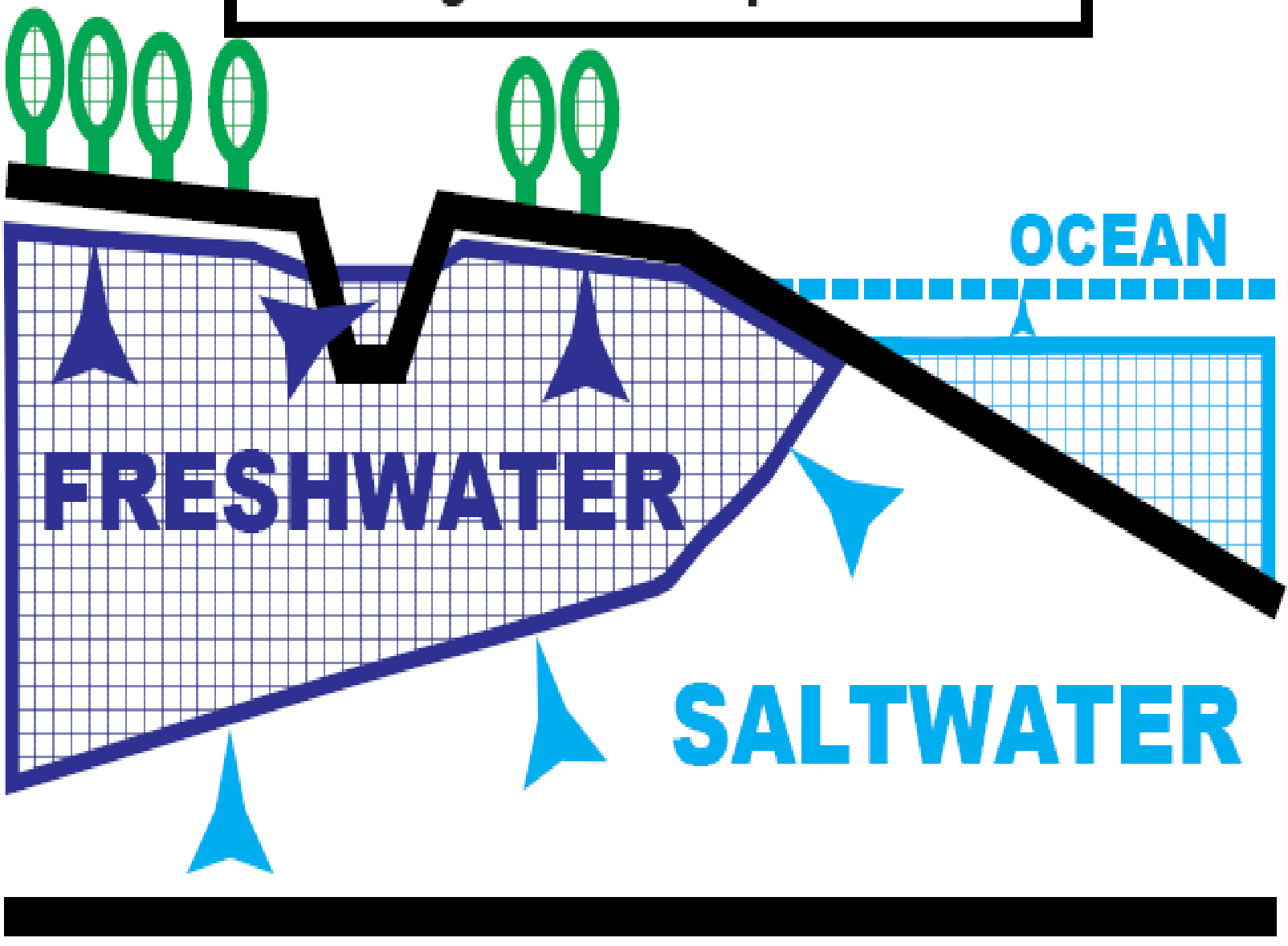
SALTWATER / FRESHWATER INTERFACE



* = ecological viable volume

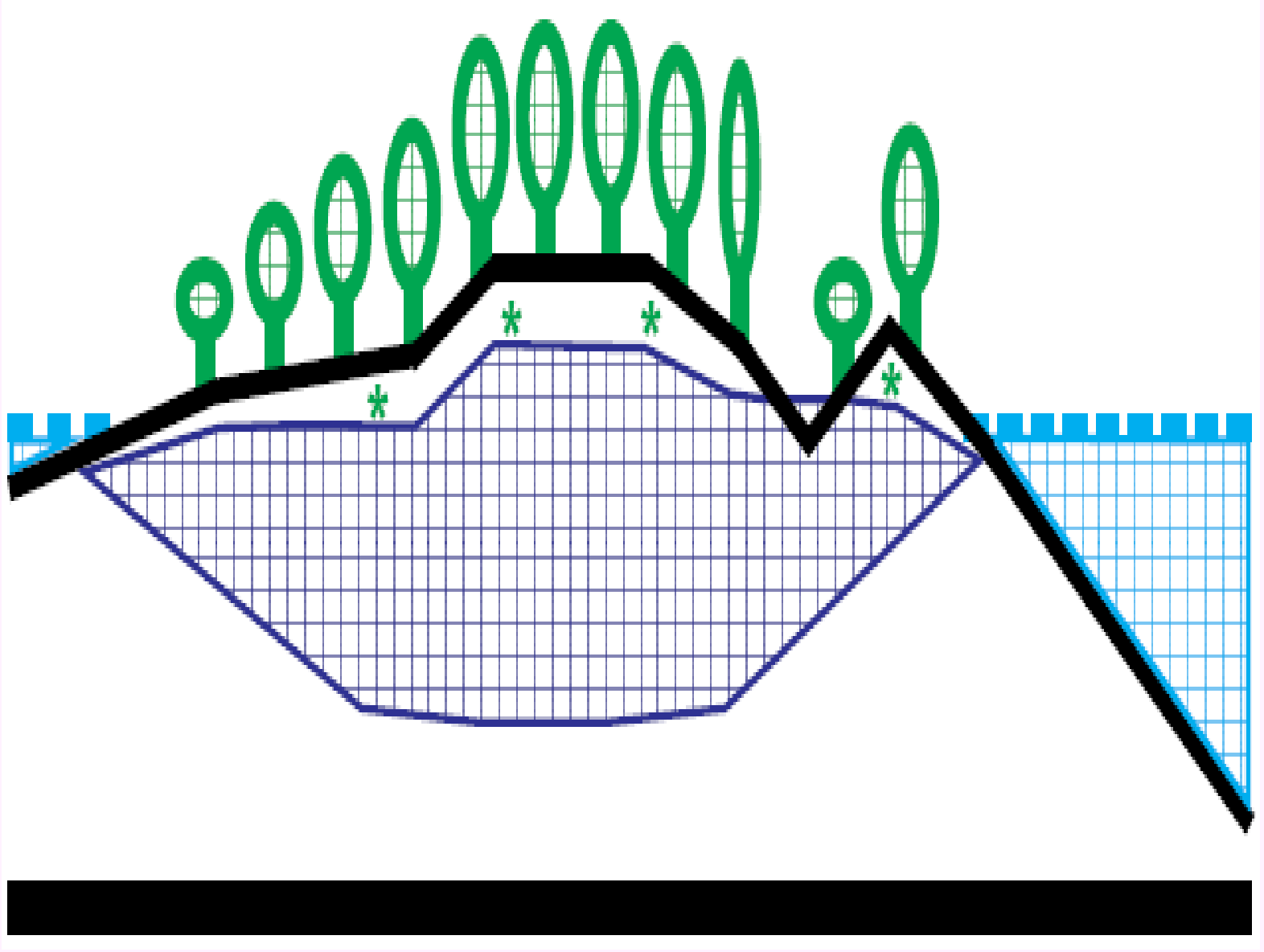
SALTWATER / FRESHWATER INTERFACE

1. ocean level rises
2. freshwater table rises
3. interface moves inland & up
4. waterway flow increases
5. ecological viable space declines



BARRIER ISLAND

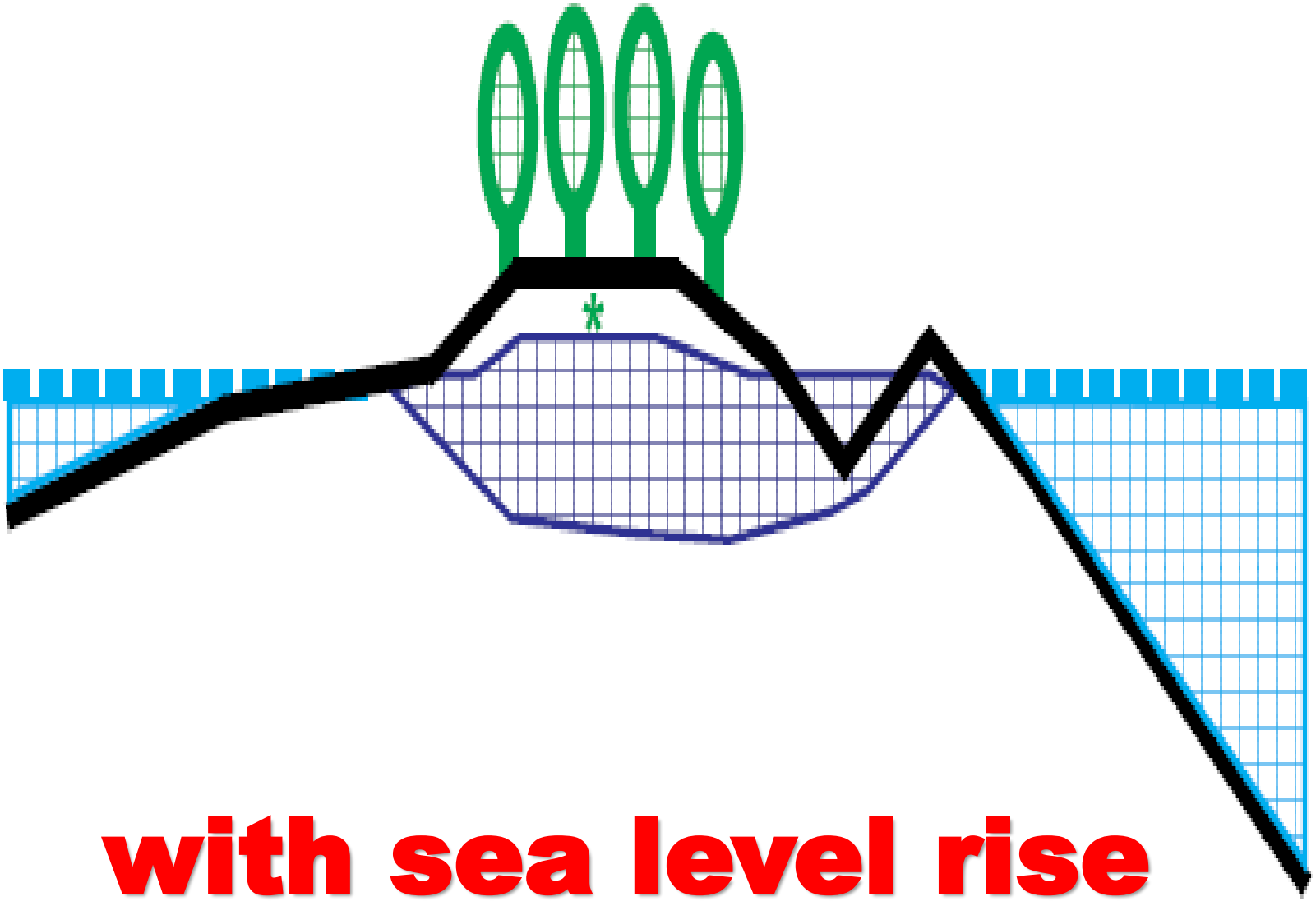
FLOATING FRESHWATER LENS



*** = ECOLOGICAL VIABLE VOLUME**

BARRIER ISLAND

FLOATING FRESHWATER LENS



with sea level rise

TREE IMPACTS

NEW TREE ENVIRONMENT

Elevated:

CO2 O3

Temperature

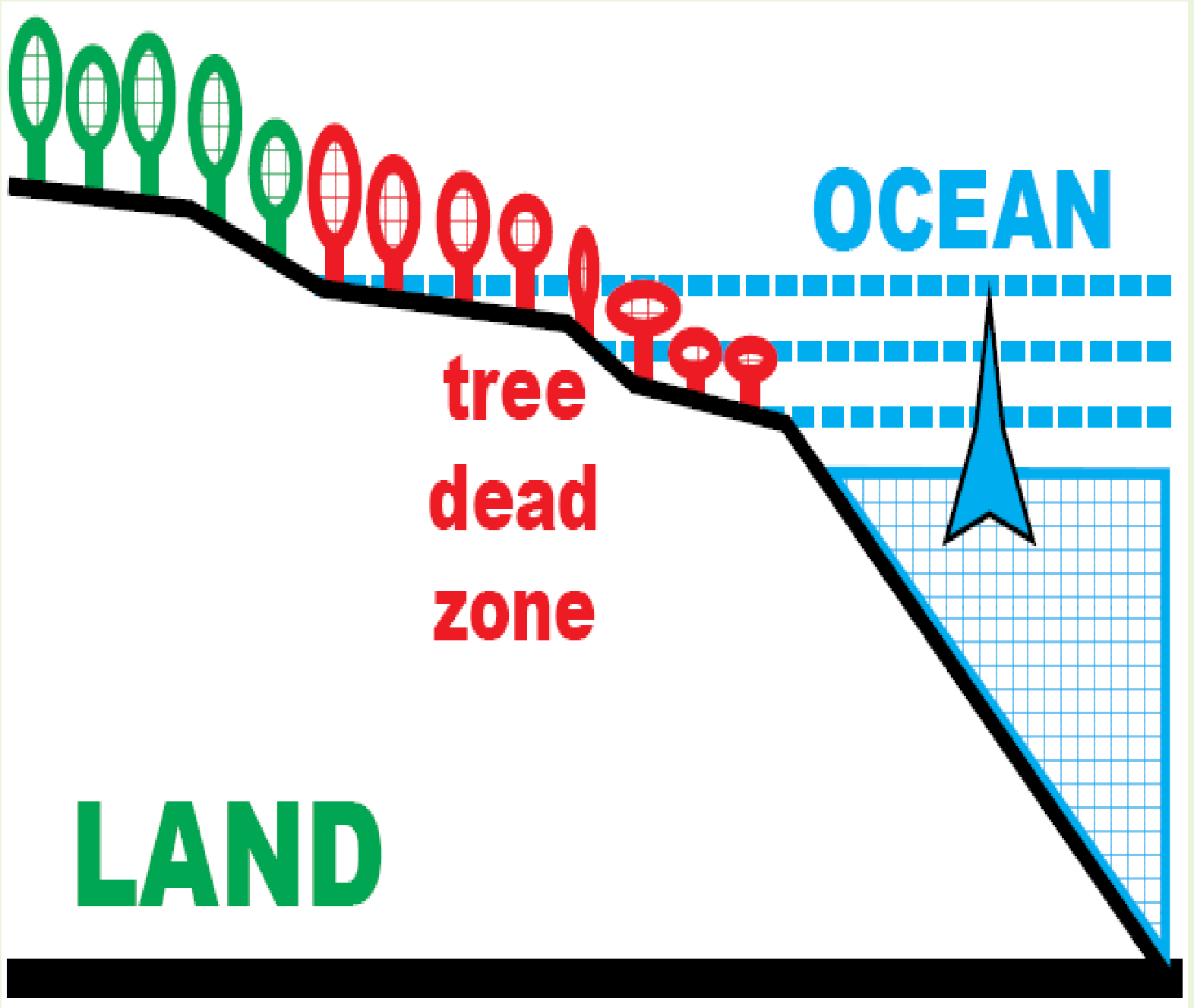
Wind Load

More:

Flooding

Drought

MARITIME FOREST IMPACTS



TREE IMPACTS

crown dieback & tree death

symptoms of sea level rise & upstream shift in salinity

understory converting to tidal marsh

Jones et.al. 2009

ISLAND TREE IMPACTS SEA LEVEL RISE

1. beach & bluff retreat
2. shoreline recession
3. island thinning
4. island washover
5. wetland conversion
6. marshland expansion inland
7. maritime forest die-off

COASTAL CHANGES

-wetland loss

-fringe forest death

-farmland & lawns into marsh

storm surges & more intense rainfall

= more flooding

Williams et.al. 2009

Climate Change
-MARITIME TREES-

more

savannah

more marsh

less trees

Ingram et.al. 2013b

Climate Change

-MORE / INCREASED-

+wind speed / gusts

+more sudden large rains

+severe erosion

+more Spring / Summer droughts

+greater evaporation

+more fire

Ingram et.al. 2013a

SYMPTOMS
Seawater Stress

--trees wilt

--roots become less permeable

--lower water potential (drought)

--Na+ & Cl- ions toxic

(especially enzyme functions)

--Na+ & Cl- ions compete with K+, Mg++ & nitrate

(show element deficiencies)

Hodson & Bryant 2012; Willey 2016

SYMPTOMS
Seawater Stress

–tree closes stomates

--tree shuts-down Ps, Chla & protein synth.

(leaf temps increase)

--no elongation growth

--leaf margins & older leaves necrotic

–huge respiration cost in roots to exclude salt

Hodson & Bryant 2012; Willey 2016

TREATMENTS
Seawater Stress

–drainage !!!!!

–freshwater rinse !!!

--small Ca++ addition

(do not increase salt level)

–small additions of K+ & nitrate with soil aeration recovery

–no micro-elements

–no greenwood pruning

Hodson & Bryant 2012; Willey 2016

CONCLUSIONS

COMING HURRICANES

NOT MORE --
BUT
MORE INTENSE

Larger peak winds
More heavy rains
More tornadoes

PROTECT
OR
RETREAT

ANTICIPATE
OR
REACT