more lines of thought about Lower Shaker Lake dam

4) Understanding the dam failure flood models
5) **Size guidance guesswork for non-flood-hazard dam redesign**

Ben Monreal
Shaker Heights
Professor of Physics, CWRU

My qualifications:

a) Taught environmental fluid mechanics at UC Santa Barbara: Physics 120 "Physics of California
b) Professional experience with complex regulatory systems, civil & geotechnical engineering
c) Live near and enjoy Lower Lake and adjacent parkland

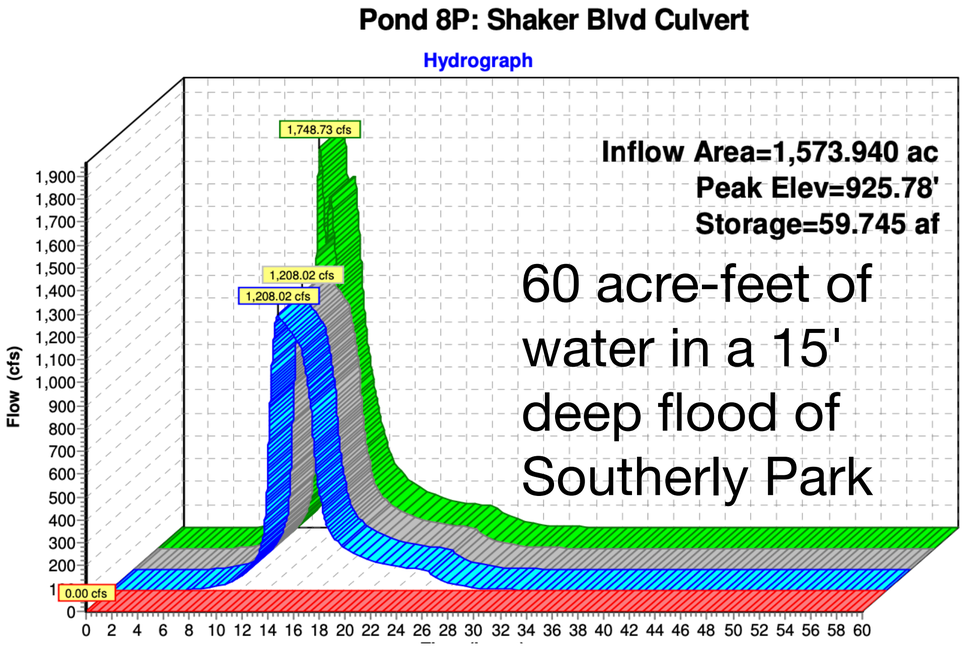
- It is ODNR's job to make sure we don't cheap out on a dam which has a "fail and cause harmful floods" risk.
  - The NEORSD $43.5M dam is *big enough* to cause floods
    - Their design would satisfy ODNR because it won't fail.
    - NEORSD's all-concrete design *is not overkill* to avoid failure.
  - A lower, smaller dam would not have as much water behind it
    - This can satisfy ODNR because the failure scenario doesn't cause floods.
    - Still nontrivial: Class II dams are required to survive "50% of PMF", i.e. a 12" storm event (either a big spillway or hardened against overtopping). Current dam is nowhere near this.
  - NEORSD's upcoming culvert work helps floodproof University Circle
    - Further details suggest (to me) it's not a big help w/r/t dam breaches

"Does this actually work?"
"How much smaller?"

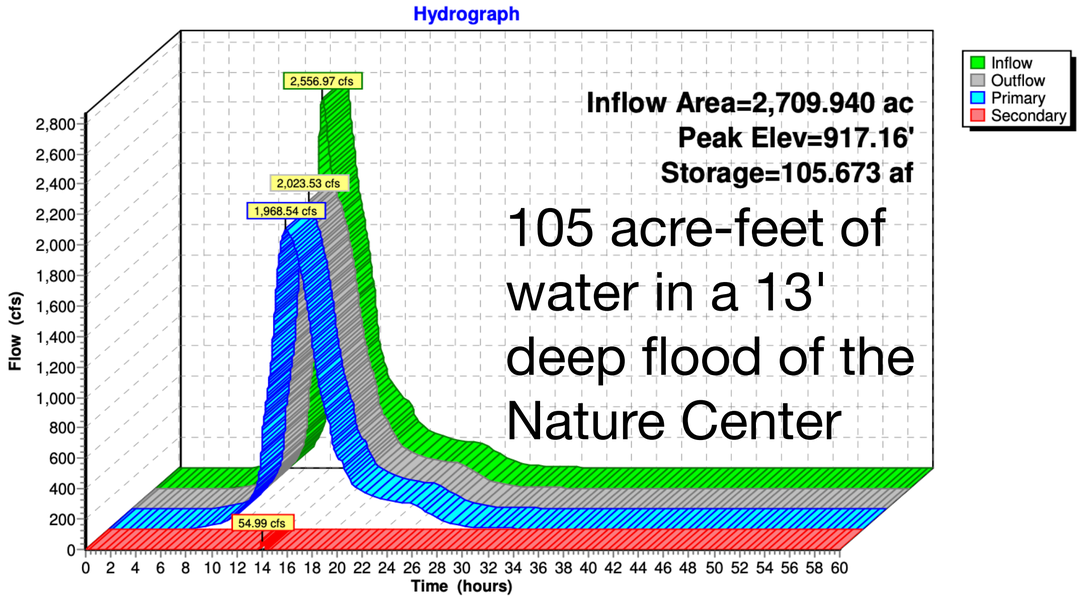
a) Expensive answer: hire AECOM to re-run flood models with a series of lower and lower dam concepts

b) Free answer: in this talk I (not an engineer) will try to read between the lines of AECOM's existing models

Step 1: could a smaller dam avoid flooding UC *in the 5" storm scenario?*

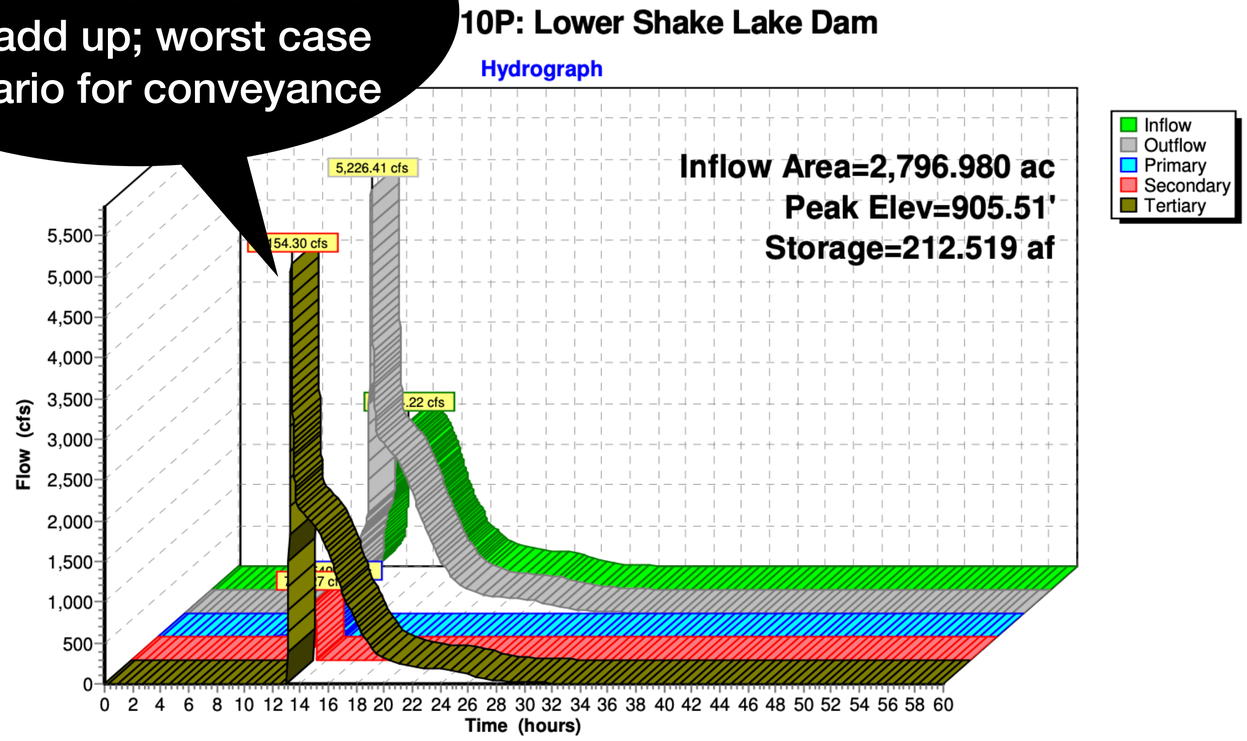


60 acre-feet of water in a 15' deep flood of Southerly Park



105 acre-feet of water in a 13' deep flood of the Nature Center

Dam breach and rainfall peak at the same time and add up; worst case scenario for conveyance



Lower Lake gets up to 905.51 elevation (212 a-f), overtops ("secondary"), then breaches ("tertiary").

Wait, I thought it was a 178 acre-foot lake? That plot says "storage 212.519 af"

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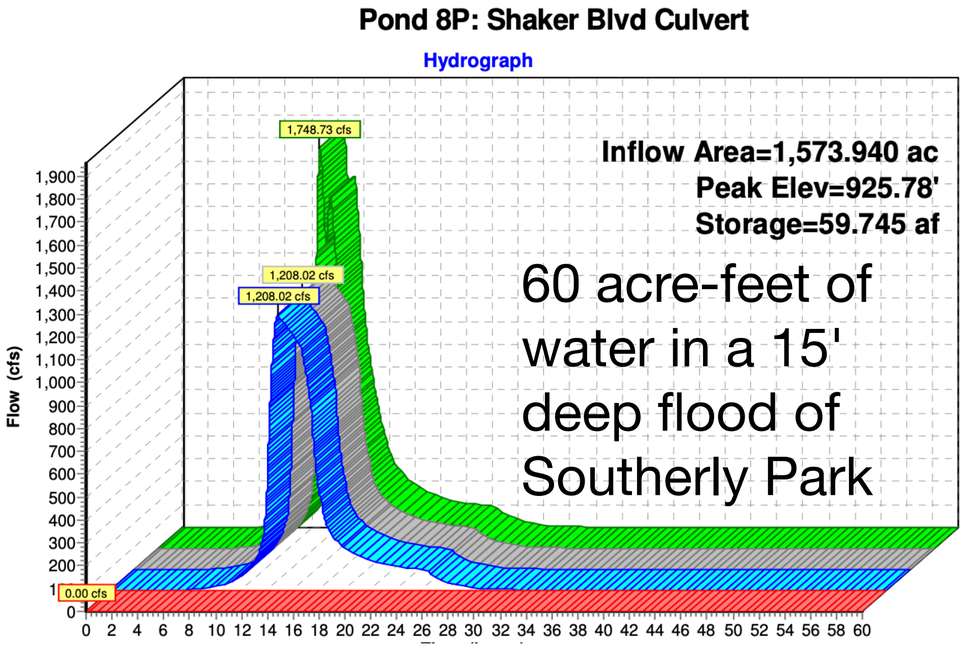

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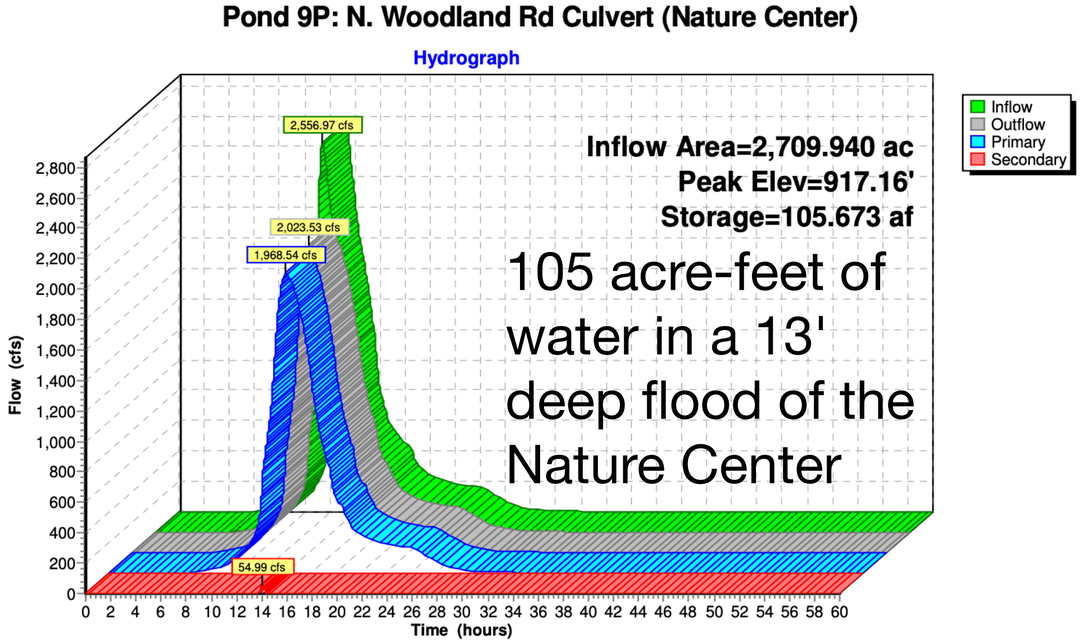

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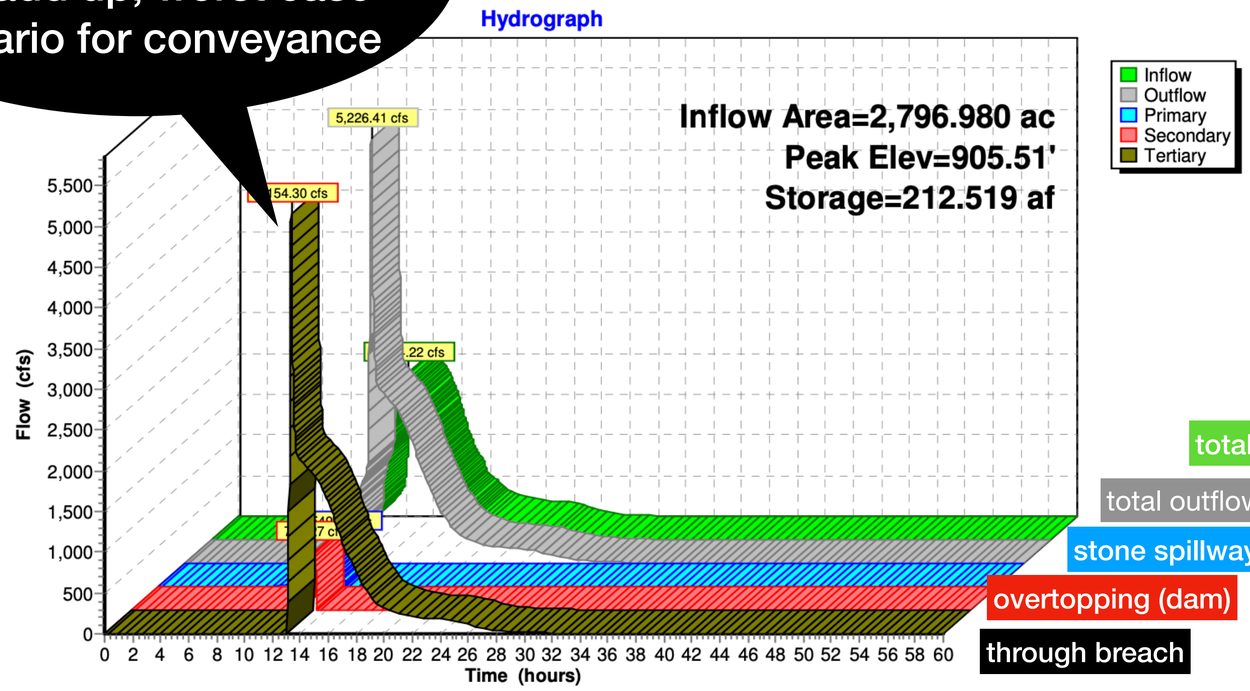

total inflow

total outflow

stone spillway

overtopping (dam)

through breach

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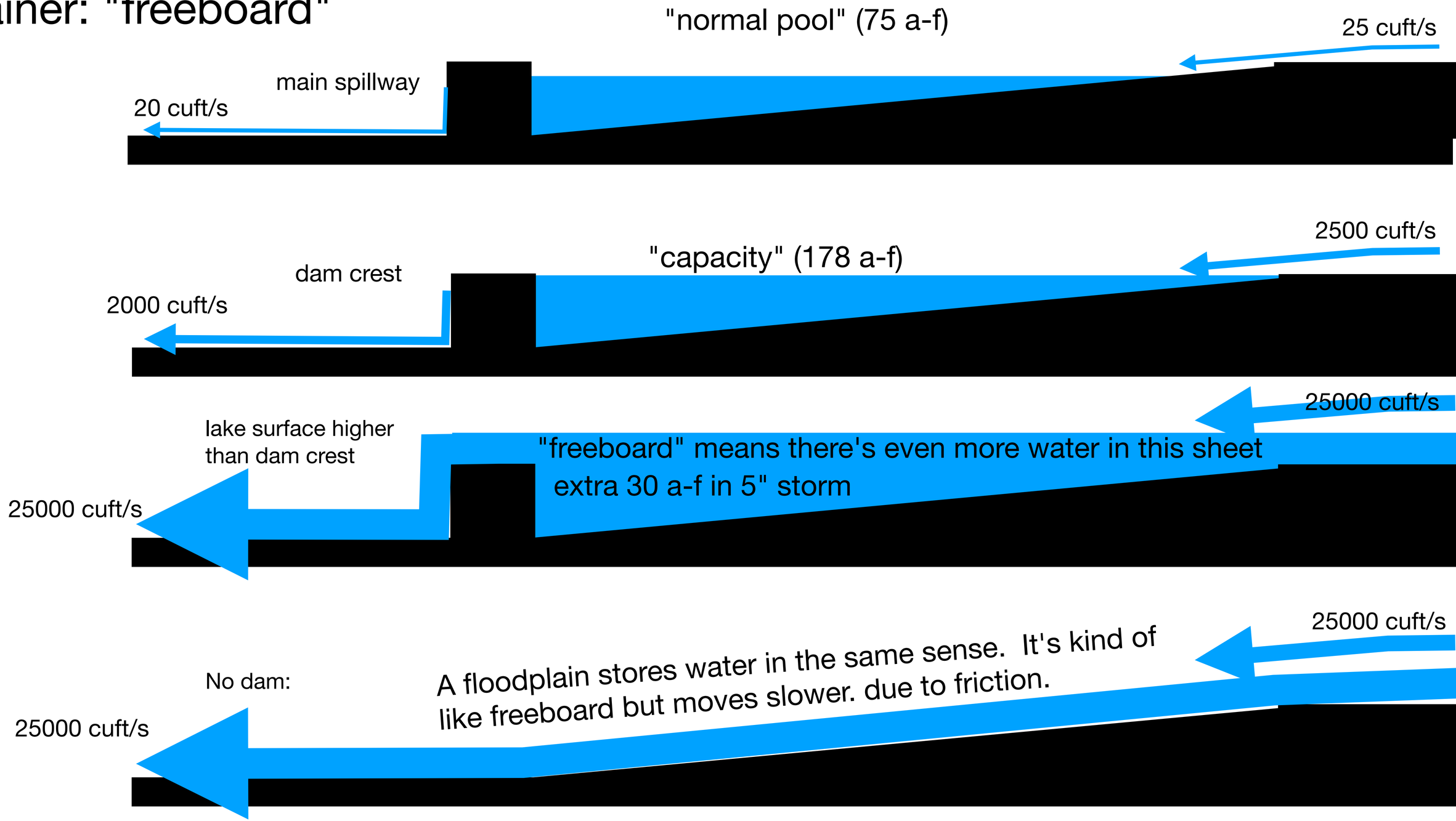

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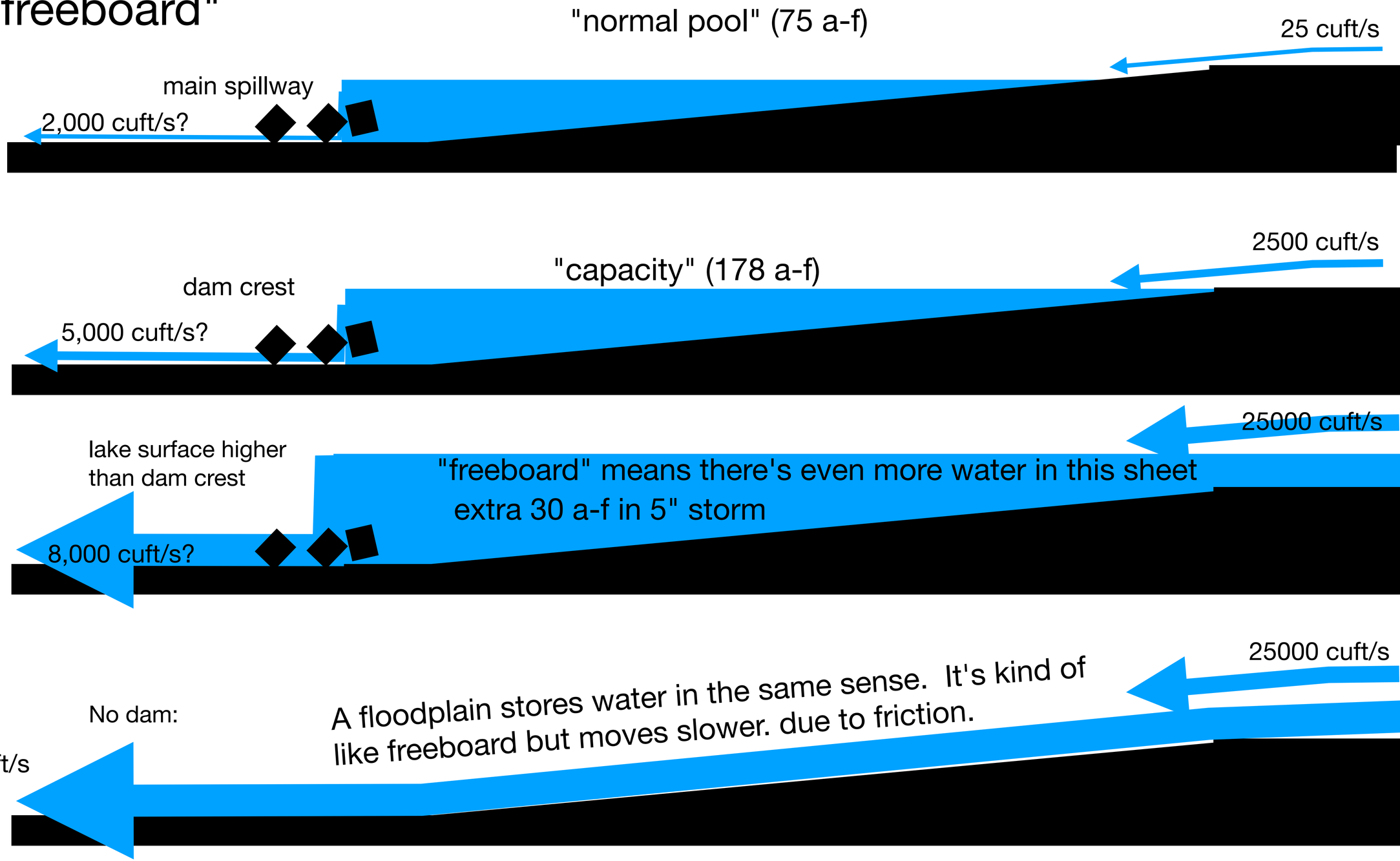


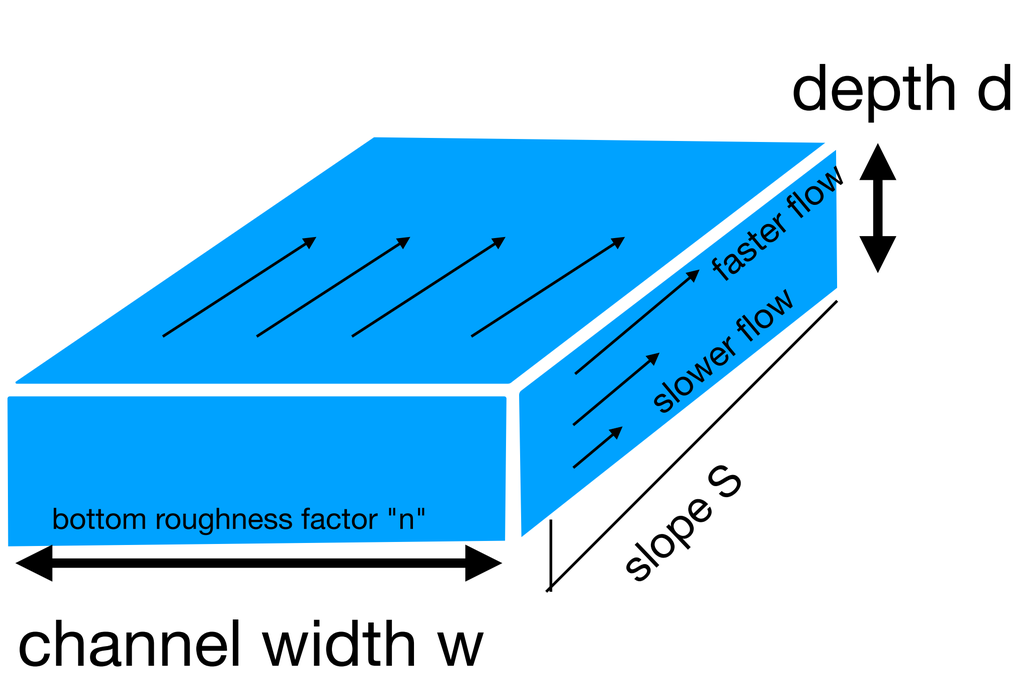
Explainer: Manning Equation

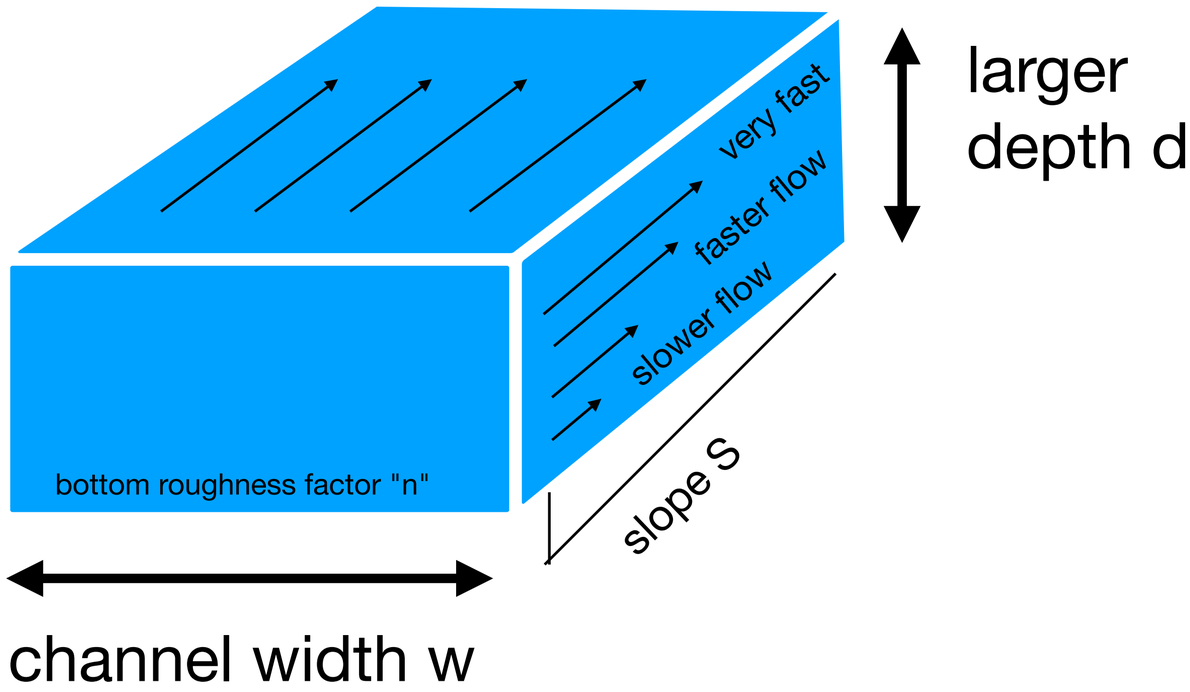
(I'm showing it simplified for wide, sheet-like flows)

$$V = \frac{1}{n} d^{2/3} S^{1/2}$$

$$Q = \frac{w}{n} d^{5/3} S^{1/2}$$

predicts the speed (V) and flow rate (Q) as a function of depth





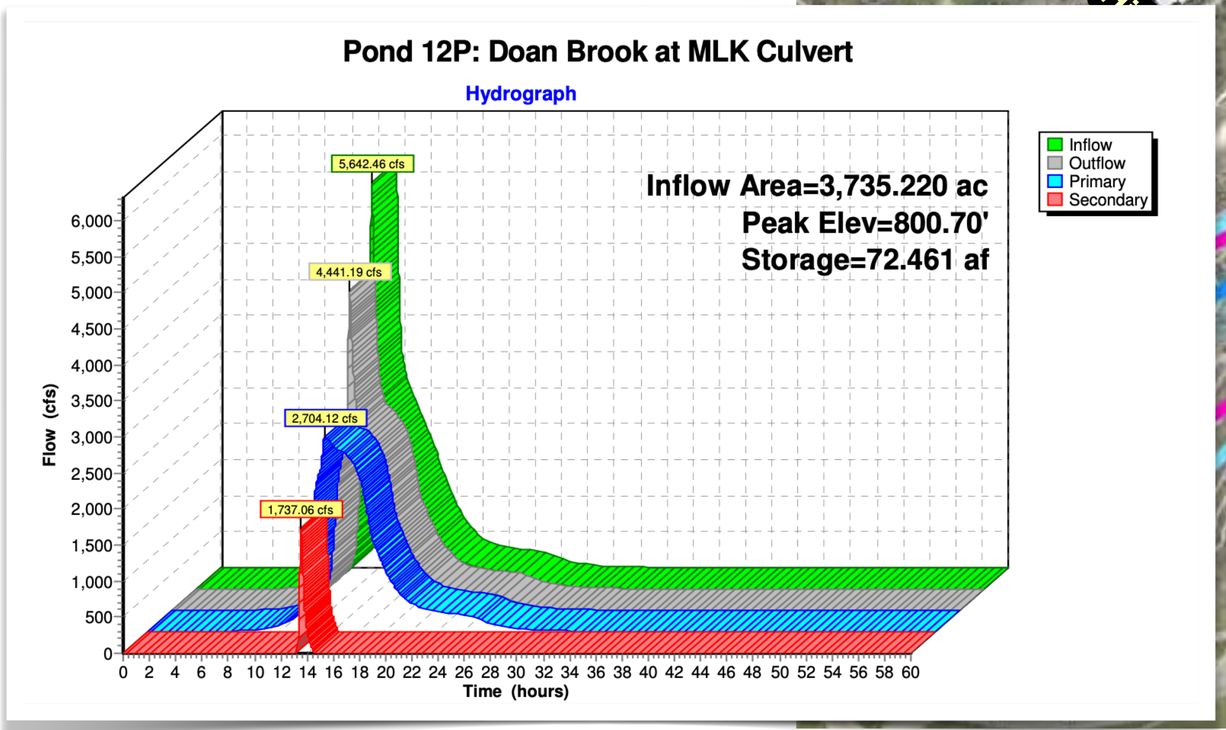
If you tell me the flow Q in a channel at one depth d, I can predict the flow at other depths.

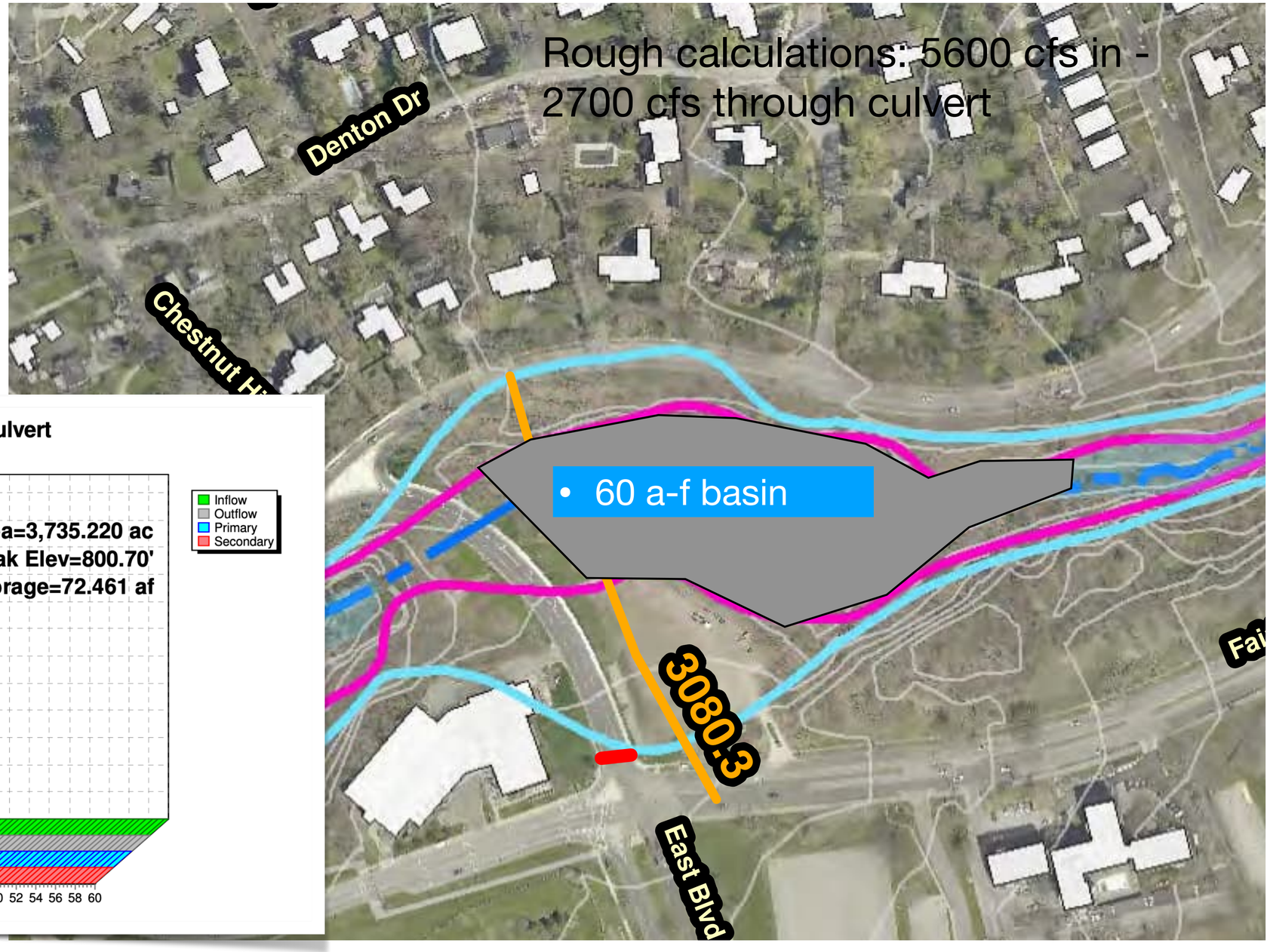
Doubling the depth *more than triples* the flow rate.
(In triangular or bowl-shaped valleys, the flow rate grows even faster. In narrow square culverts it will grow more slowly.)

University Circle can handle anything that comes through the under-MLK culvert (max 2700 cfs) with room to spare. The only way for water to overflow Ambler Park is for it to overtop MLK (wide sheet flow = sudden high Q).

A breach of "60 acre-feet suddenly plus 4 acre feet per minute" will not overtop MLK here.

Here's AECOM's breach of a 212 a-f lake during a 5" storm.





Order-of-magnitude calculations from 5" storm model: breach is 12.5' deep from 904.5' dam crest. Model shows 5600 cfs *peak outflow,* but let's approximate it as a *constant* 5600 cfs.

5600 cfs (in) - 2700 cfs (out through culvert) = 2942 cfs (accumulating in basin)
2,600,000 cuft (60 acre feet capacity) / 2942 cfs (accumulation rate) = basin fills in 900 seconds.
900 seconds (time before overtopping) x 5600 cfs (in) =5,000,000 cuft (112 acre feet) has left the lake

In this event, more than half the lake water has come in before MLK *starts* overtopping. The remaining half of the water comes in *more slowly* and does not sustain the overtopping for long. That's why the flood is so minor.

Let's use these numbers to scale down to a smaller dam/lake:

Suppose we have a 901.5' dam crest and a 150 a-f lake
If dam crest is at 901.5 then the same breach is 9.5' deep (shallower, factor of 0.75)
Manning formula tells us a factor of 0.75 shallower depth is *at least* a factor of 0.62 lower flow rate. So the breach flow is 5600 x 0.62 = 3500 cfs at most.

3500 cfs (in) - 2700 cfs (out through culvert) = 800 cfs (accumulating in basin)
2600000 cuft (60 acre feet capacity) / 800 cfs (accumulation rate) = basin fills in 3250 seconds.
3250 seconds (time before overtopping) x 3500 cfs (in) =11,375,000 cuft (261 acre feet)

My estimate: this dam/lake is not big enough to overtop the MLK embankment.

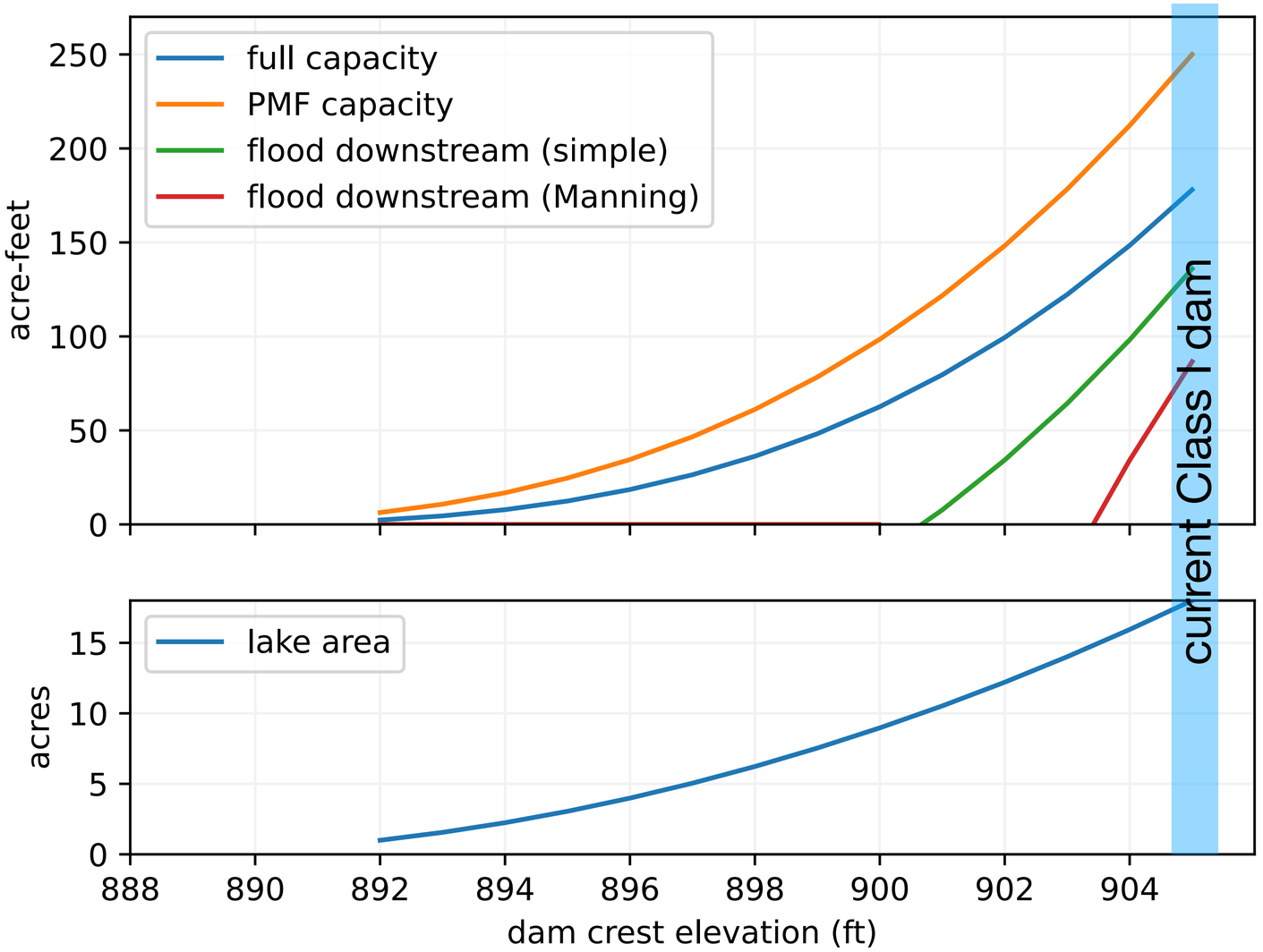
(I *could* do a differential-equations version of this, but if you want accuracy please just hire engineers.)

Lake size/capacity vs dam height

How seriously to take these numbers:

- NOT SERIOUS ENOUGH: "these curves are completely meaningless, you amateur knowitall"
- GOOD: "whether or not the slopes are exactly right, it's clear that the flood hazard goes down fast-ish when we lower the dam but still have a good-sized lake"
- TOO SERIOUS: "we have hired an earthmoving contractor to lower the dam crest to 901 feet"

"I insist on a dam whose 100-y breach doesn't overtop the MLK embankment at all. Is that possible?"



Assumptions used in this calculation:

- current dam is 17' high, lake area 18 acres, volume 178 acre-feet
- current lakebed is a tapered wedge shape,
  - full volume scales as H^3
  - surface area scales as H^2
- PMF event adds 4' freeboard but doesn't increase area (no floodplain activated)
- after breach, upper floodplain (upper canyon, Coventry/Fairhill, old lakebed) detains 54 acre-feet, MLK road embankment detains 60 acre-feet) long enough to not add to flood wave

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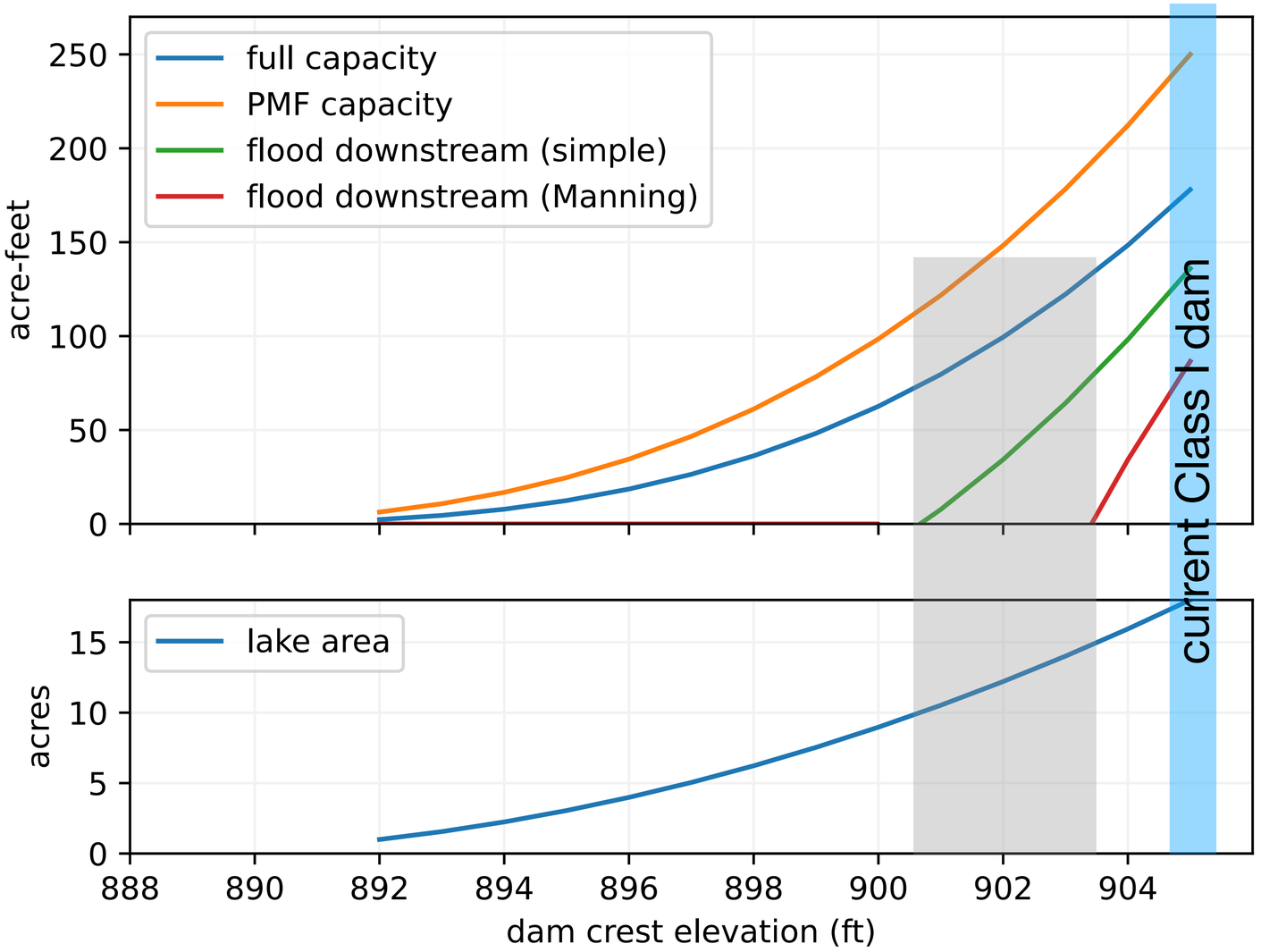
dam elevation around 901.5' to 903.5', volume 75 to 140 acre-feet, area 10 to 15 acres



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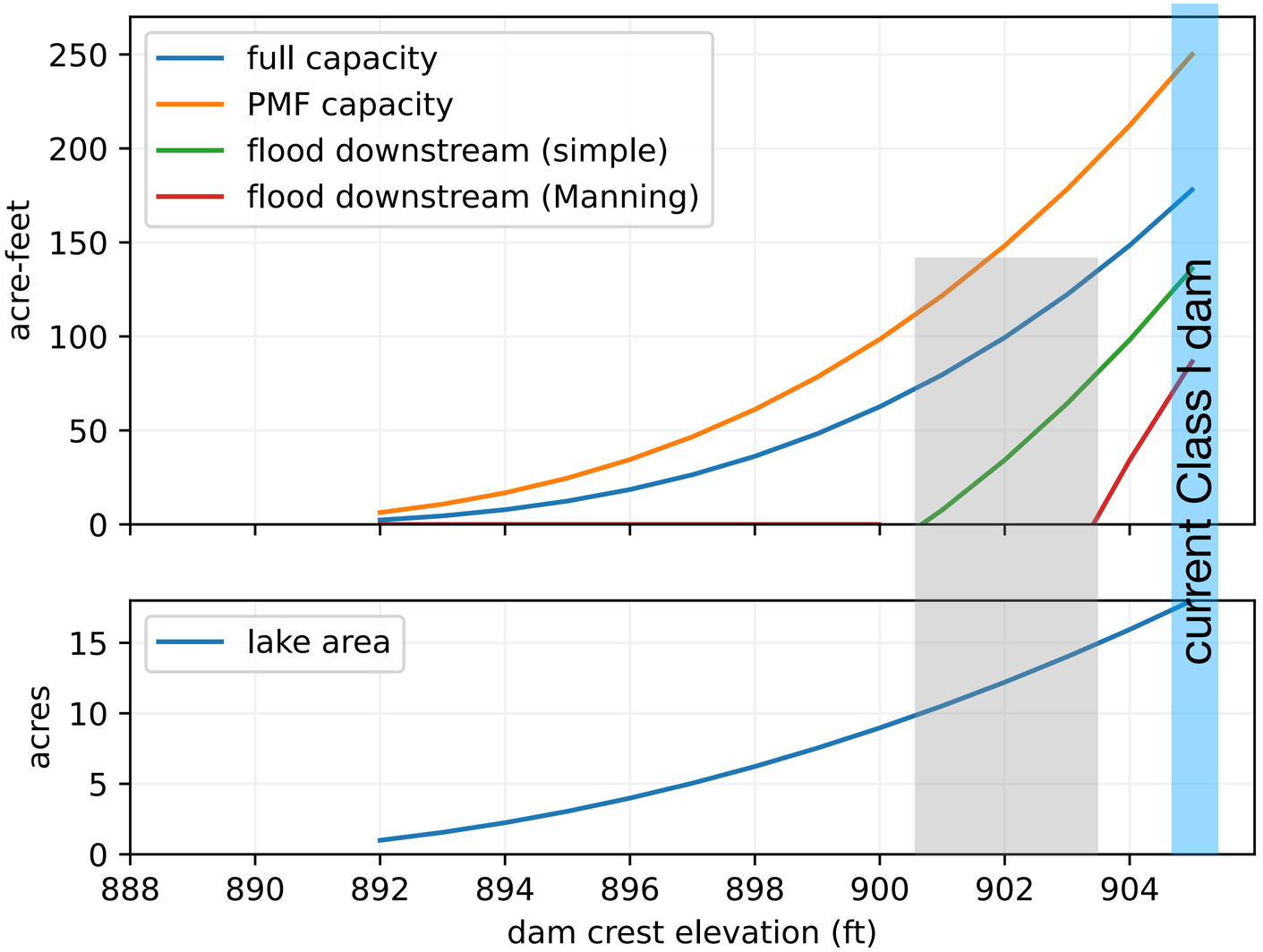

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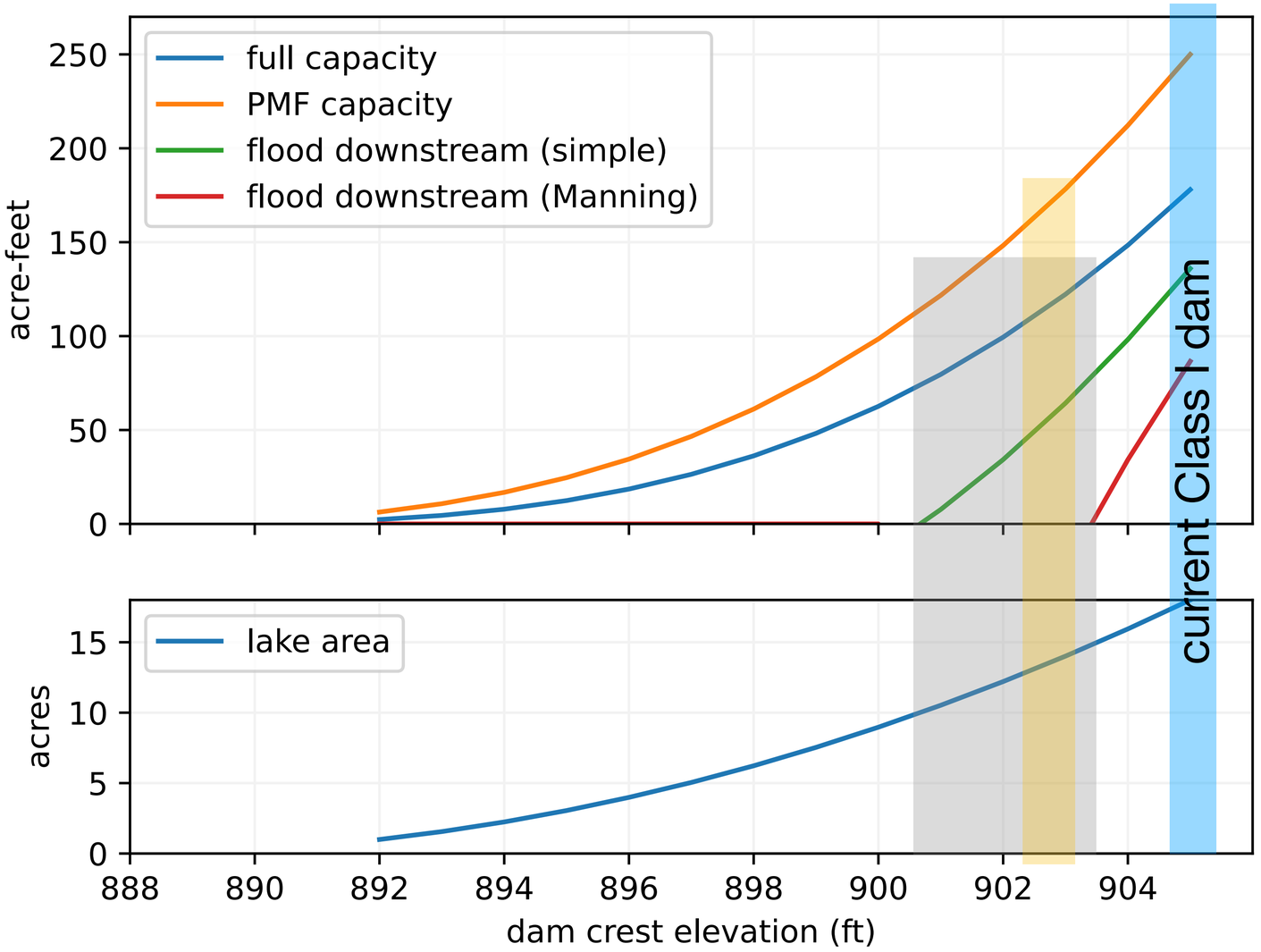
dam elevation around 903'; capacity 125 acre-feet, area 13 acres



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A smaller lake

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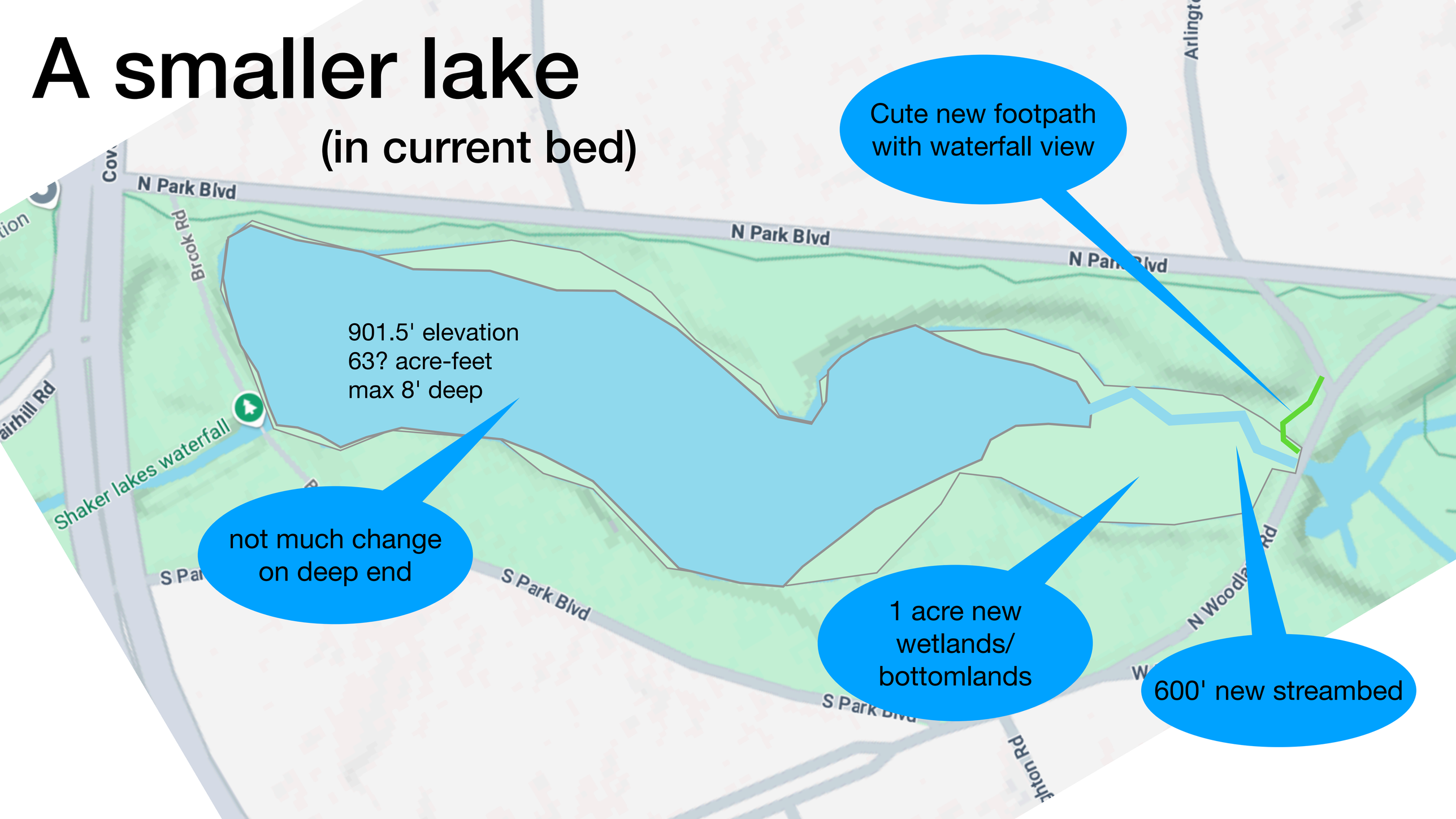
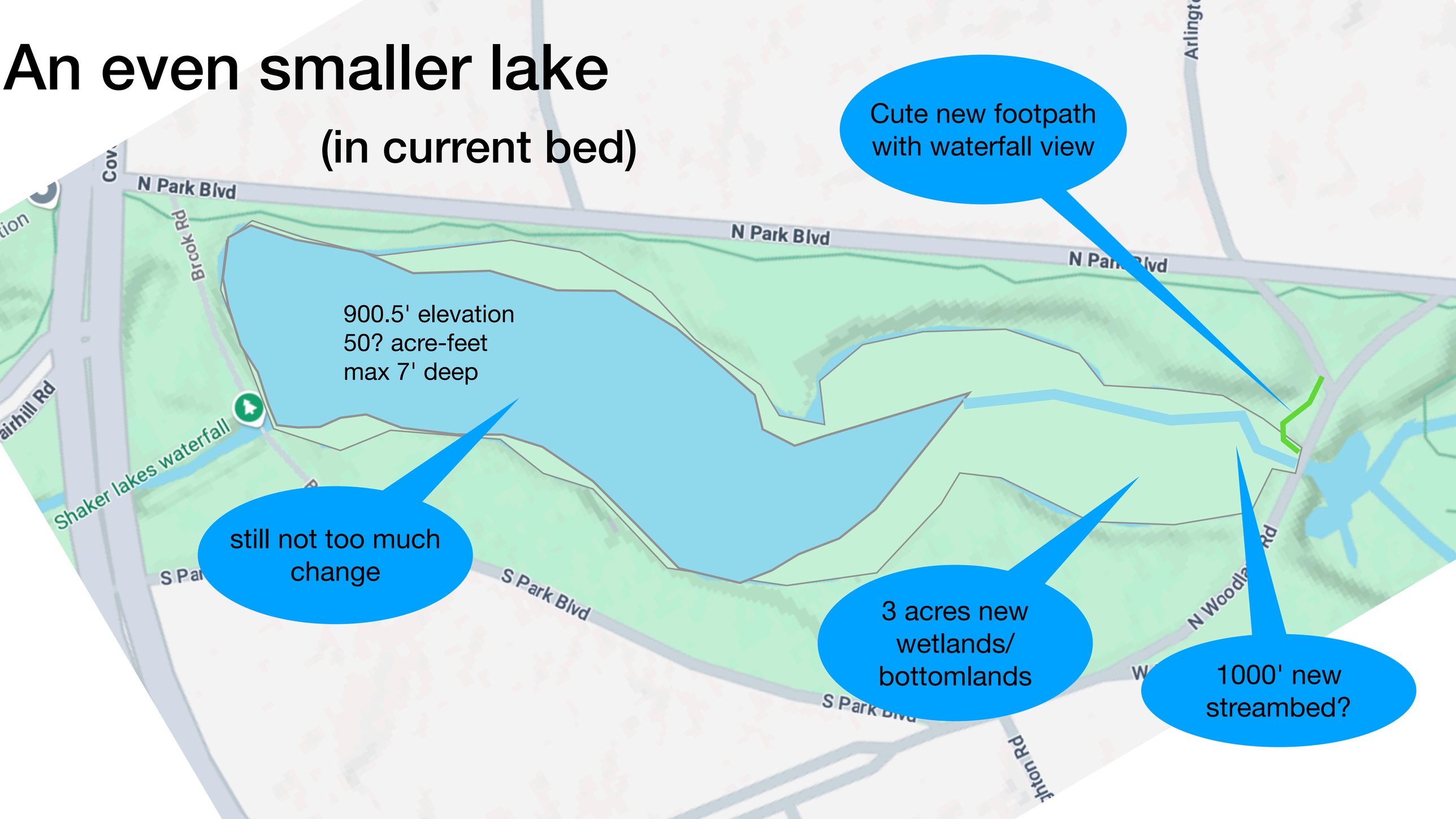


An even smaller lake

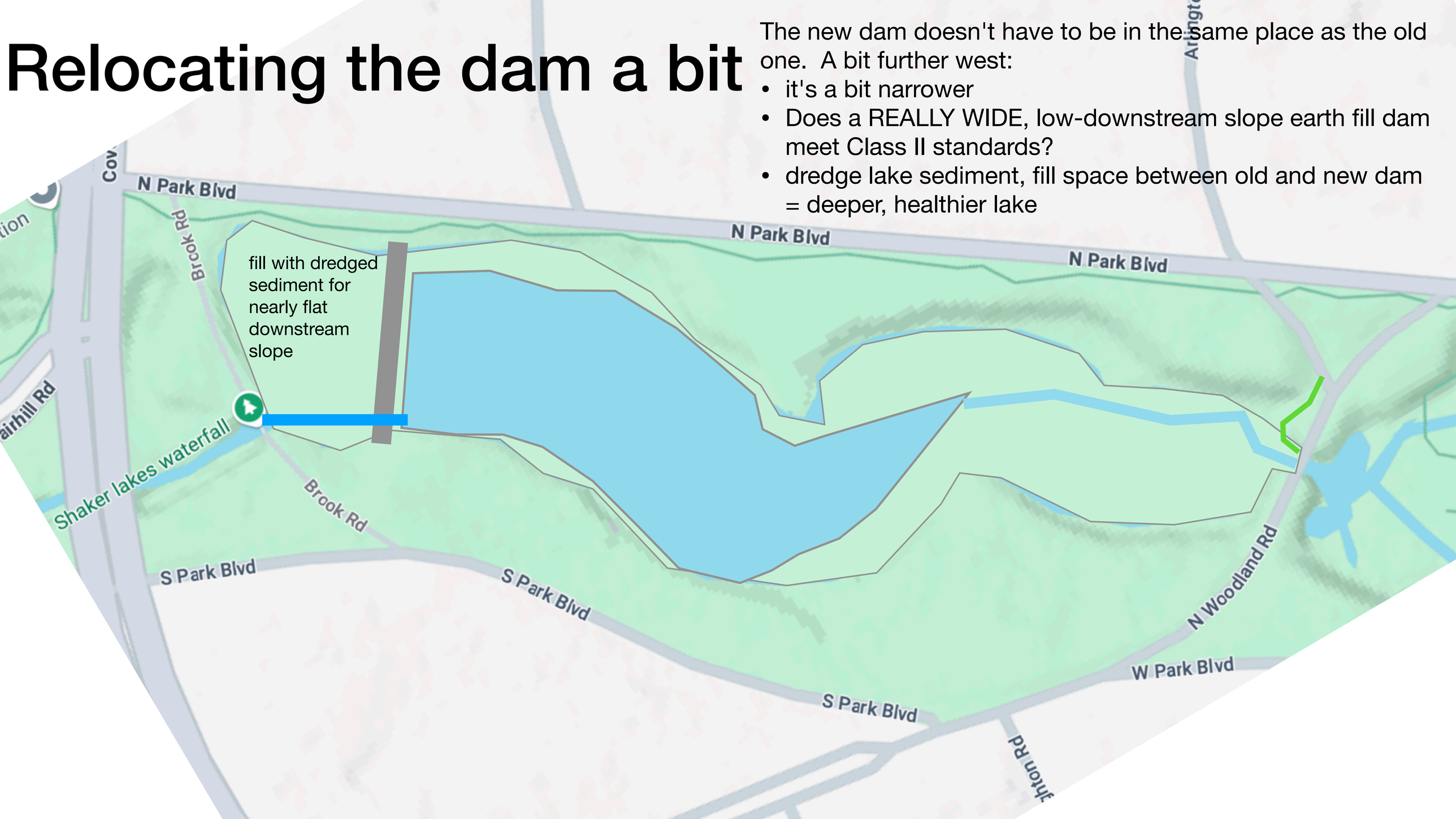
(in current bed)



Relocating the dam a bit

The new dam doesn't have to be in the same place as the old one. A bit further west:

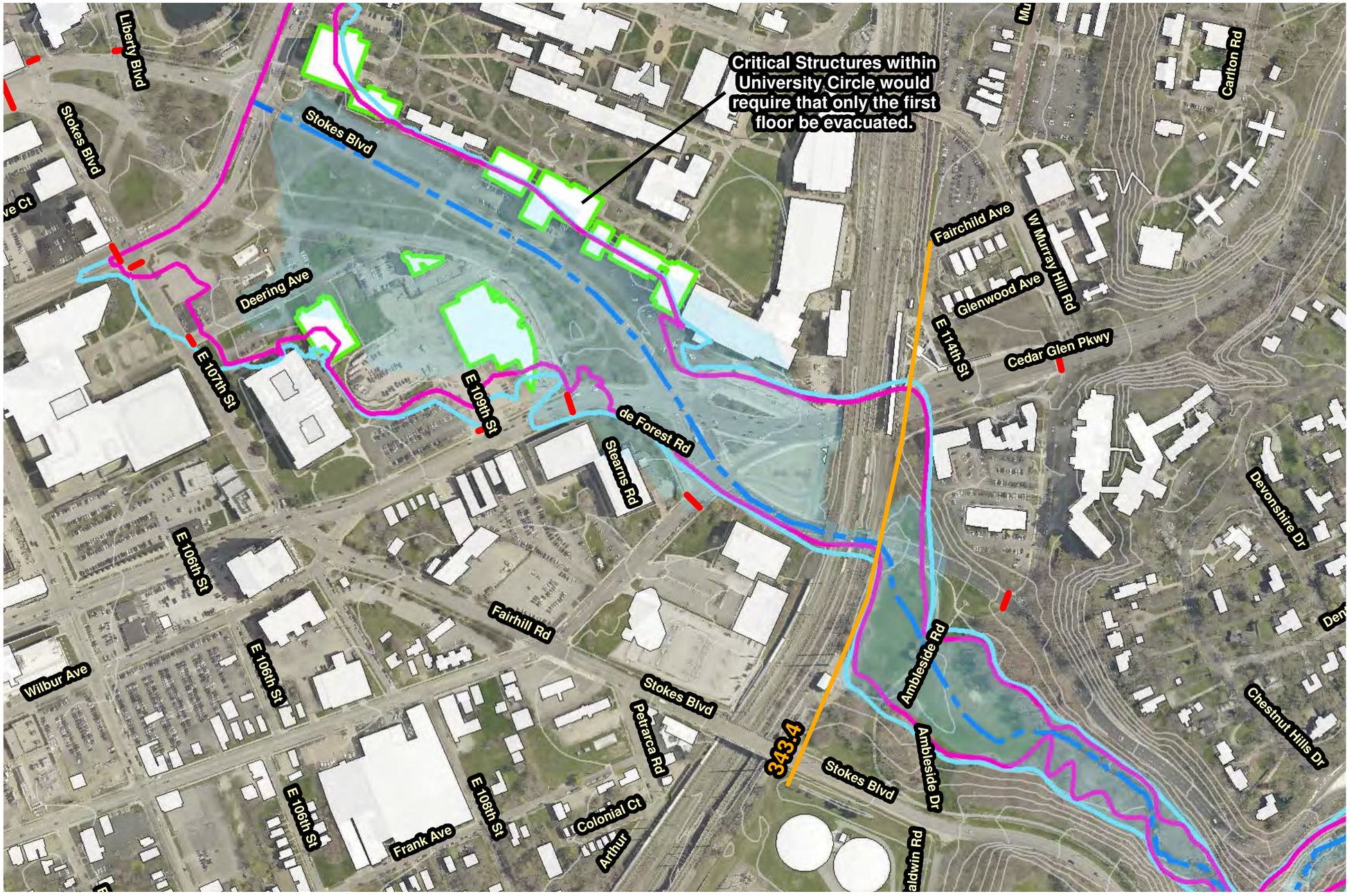
- it's a bit narrower
- Does a REALLY WIDE, low-downstream slope earth fill dam meet Class II standards?
- dredge lake sediment, fill space between old and new dam = deeper, healthier lake

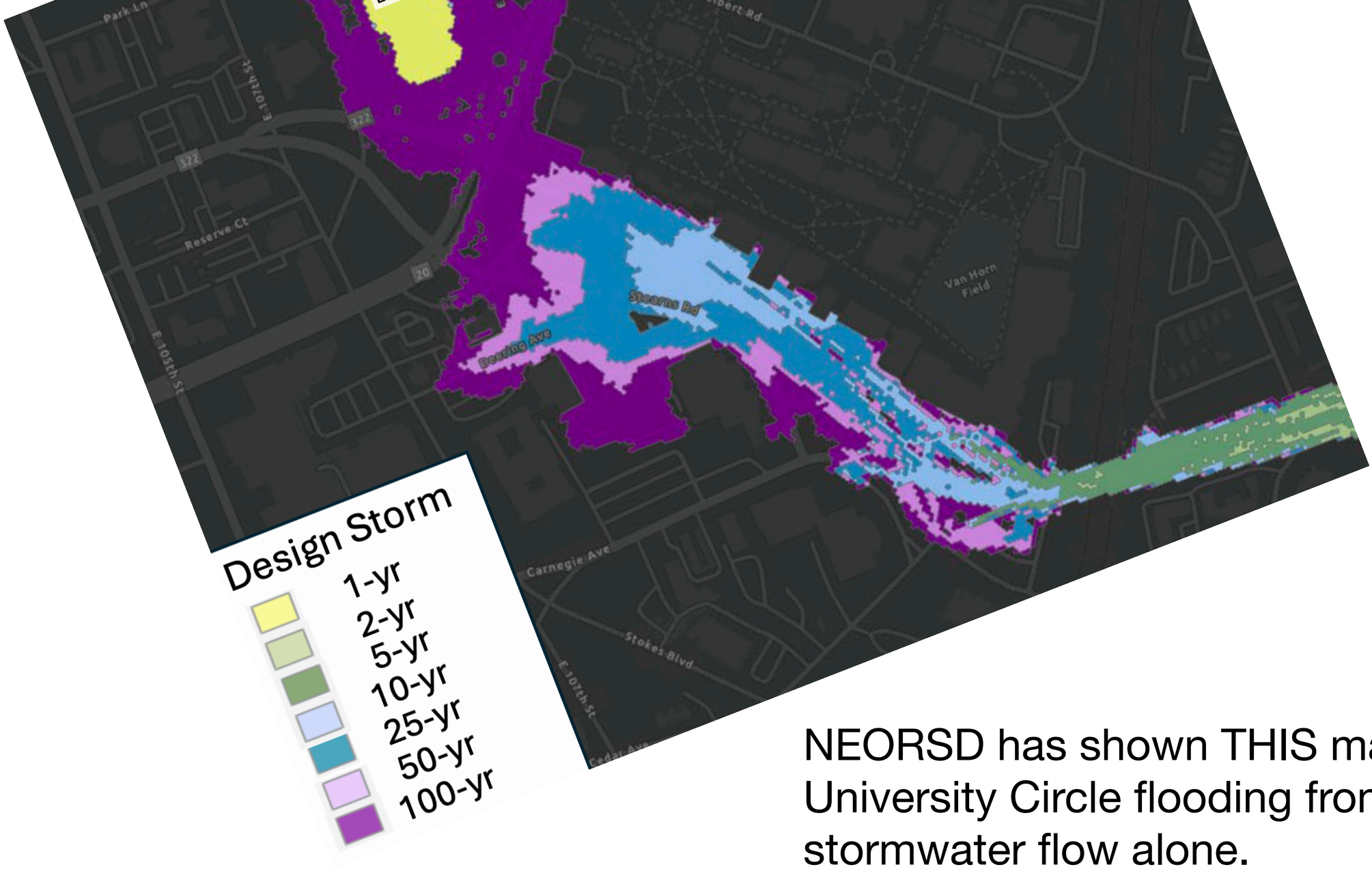


Do we need to understand the new NEORSD culvert capacity to understand Lower Lake dam safety?

AECOM says:

- Pink: 5" rain plus breach
- Blue: 24" rain plus breach





NEORSD has shown THIS map of University Circle flooding from stormwater flow alone.

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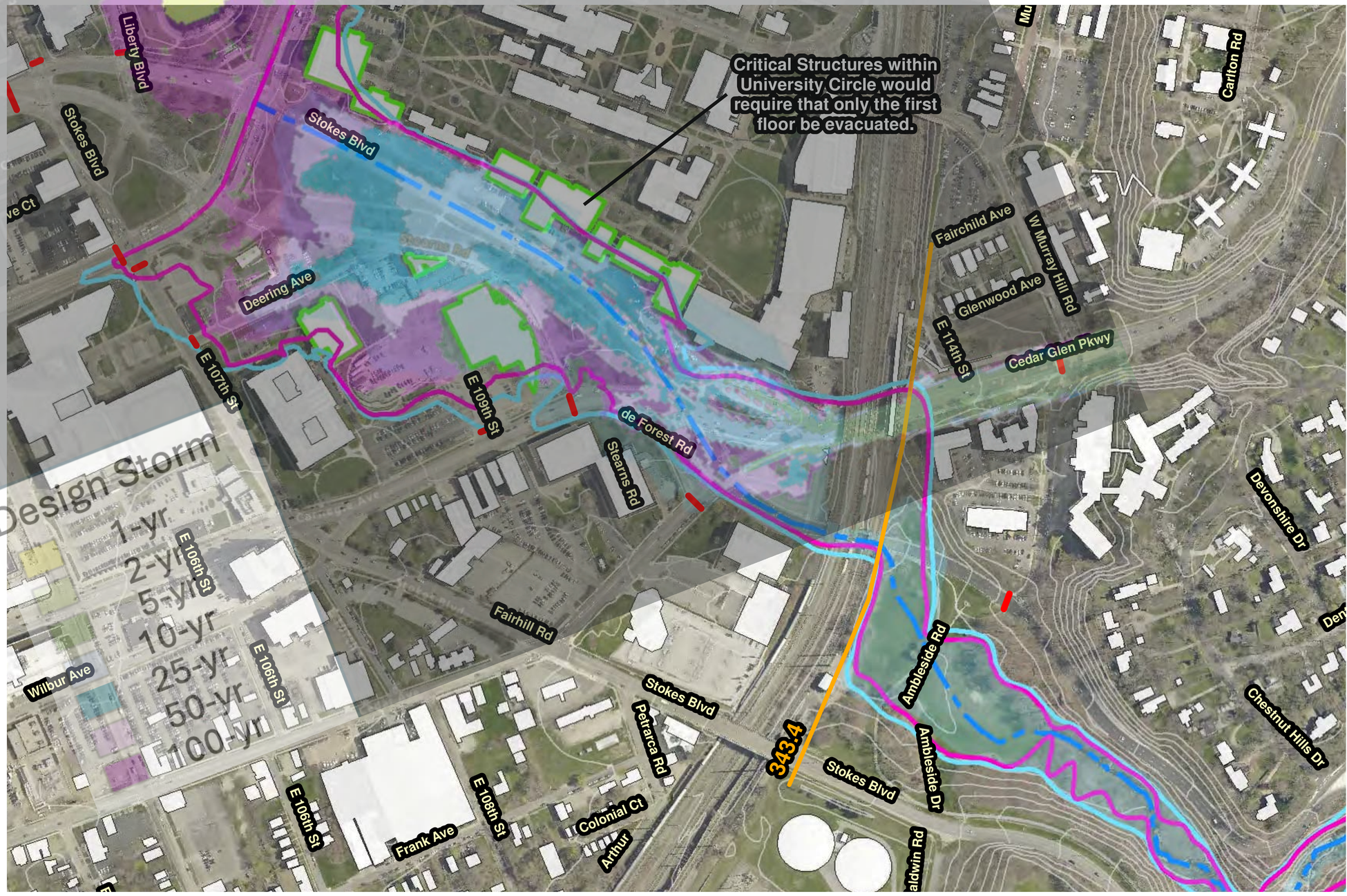
Compare to NEORSD stormwater model in a 5" rainstorm (pink area labeled 100 y) WITHOUT a dam breach

They're very similar!



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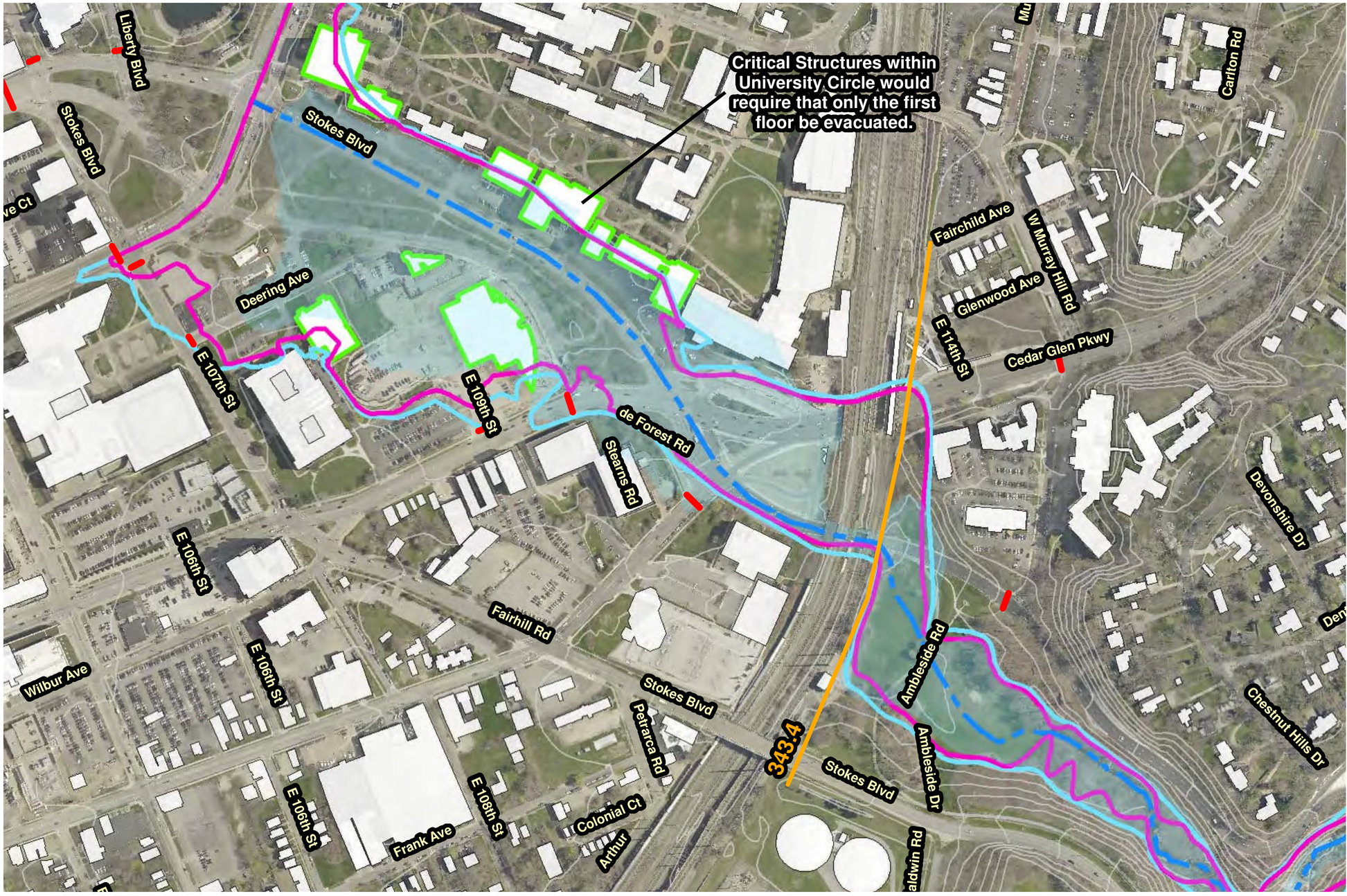
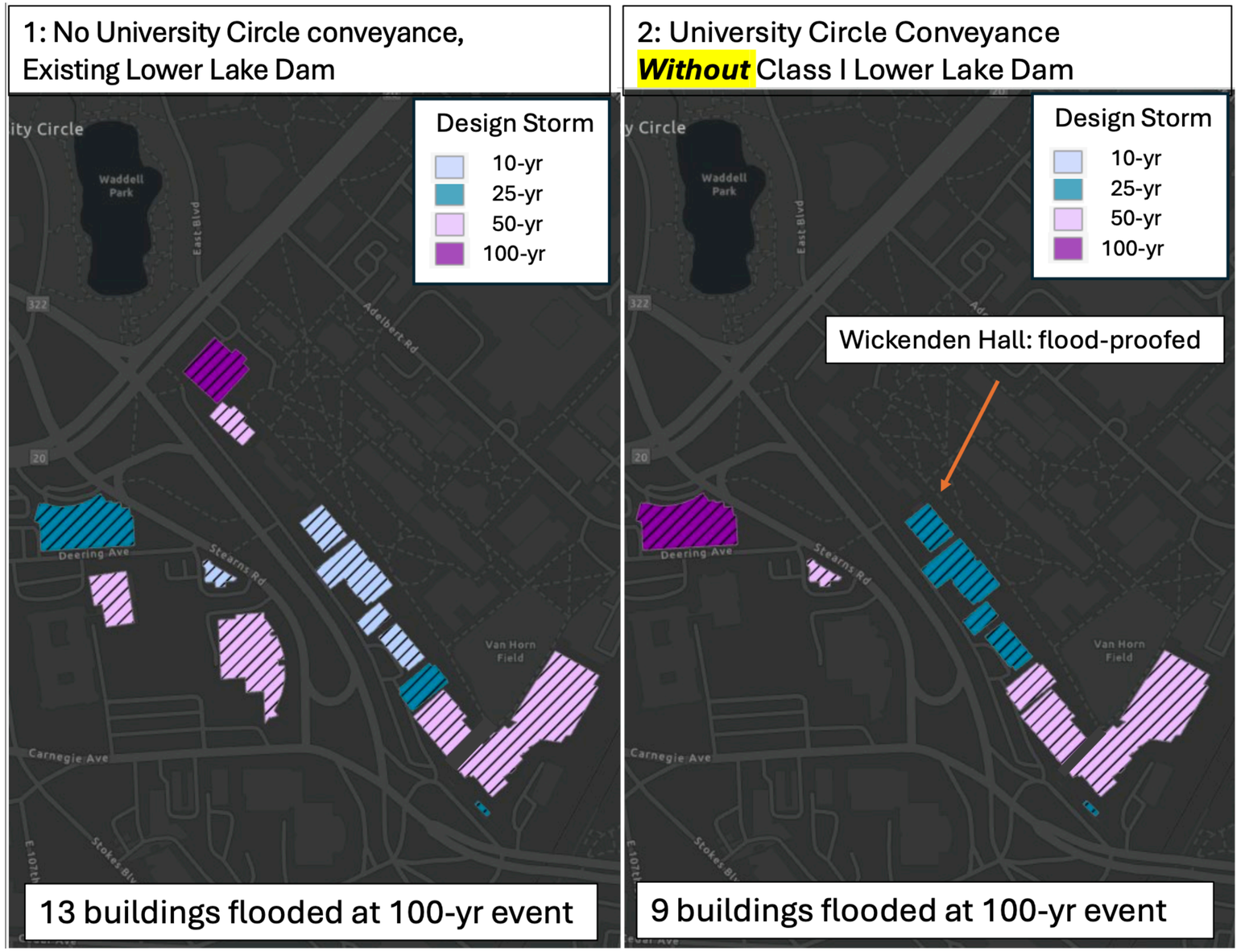


Can we guess from this what the new culvert conveyance is?

Roughly: 100-y flood map with new culvert is similar to 25-yr flood map with current culvert.

That suggests to me that the new culvert carries ~2000 cuft/s in the 100y storm = 2.7 acre-feet per minute

My guess: this may be a near-doubling of this conveyance, which is *relevant* to how we describe Lower Lake breach flood risks but is not a wholesale conceptual change.



NEORSD's newest flood model shown at Shaker/Cleveland City Council

- **Conclusions**
  - The dam-breach scenarios modeled by AECOM for emergency planning purposes *just barely* put lake water into University Circle.
  - Models that show large/damaging University Circle flooding are demonstrably showing it is *not* the modeled dam breach that causes the damage.
    - It's not clear if ODNR is allowed to account for this distinction.
  - AECOM data includes useful parameters to guide further thought
- **My opinion:** Lower Lake stakeholders should have the option of a downsized dam
  - Hazard reduction to Class II really sounds within reach
  - I hope these slides provide education and encouragement (not definitive engineering statements)