Building Downwash Modeling with AERMOD

Lloyd L. Schulman and Joseph S. Scire
Exponent, Inc.

10th Conference on Air Quality Modeling
March 15, 2012

Outline of Comments

- Changes made to the downwash code with AERMOD version 11059 lead to significant, but unverified, increases in predicted concentrations for wide buildings
- Even without the code change, documented over-predictions exist for very wide buildings

GEP Stack Height

- GEP is defined in the Stack Height Regulations as the maximum of:
  - 65 meters
  - H + 1.5L (formula height)
  - Height demonstrated from a fluid modeling study that ensures that emissions do not result in "excessive concentrations" (increase of maximum ground-level concentrations more than 40% and causing or contributing to a violation of a standard)
- Based on EPA wind tunnel studies and scientific literature

AERMOD Downwash Change

- Change described in MCB #4 (2-28-2011)states:

  "Subroutine WAKFLG was modified to no longer ignore potential downwash effects for stack heights that equal or exceed the EPA formula height. The determination of whether building downwash effects apply is based on the criterion implemented within the PRIME downwash algorithm."

- Previous policy was to only model downwash effects for stacks less than GEP formula height

AERMOD Downwash Change

- Change was made to eliminate discontinuities for stacks straddling the GEP formula height
- The change will be justified by a pending clarification memorandum
- No consequence analyses provided by EPA
- No public comment or review of this significant change to the model

AERMOD Downwash Change

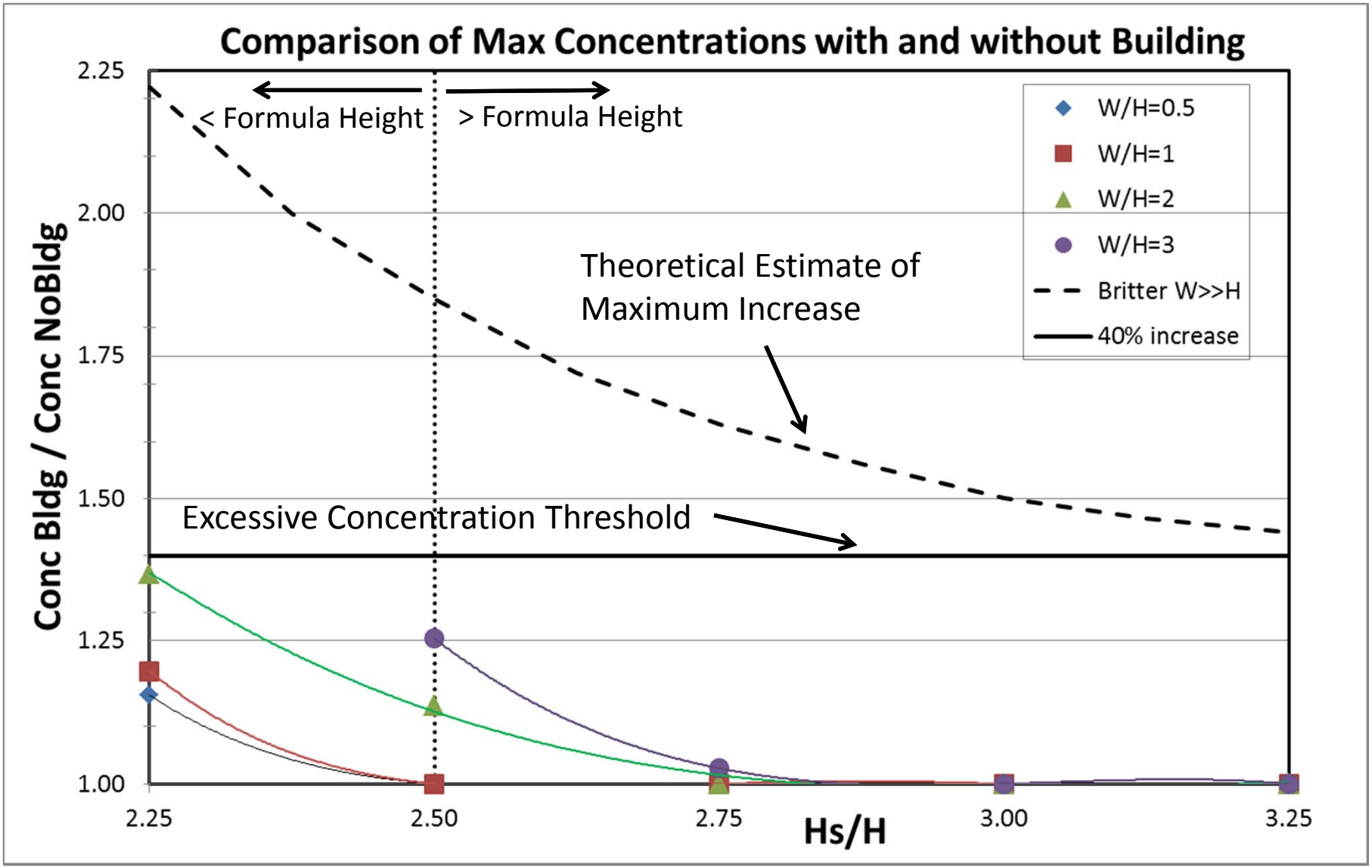
- There <u>is</u> downwash at formula height for most buildings, but does PRIME model it correctly?
- PRIME algorithm was developed using data from buildings with W/H <4.4 and sub-GEP stacks
- Over-prediction already demonstrated for very wide buildings
  - unrealistically long projected lengths from BPIPPRM
- Allowing downwash for stacks greater than formula height will exacerbate this problem.
- Proposed definition of an effective building length is a step in the right direction but needs further testing and confirmation

W/H for Evaluation Databases

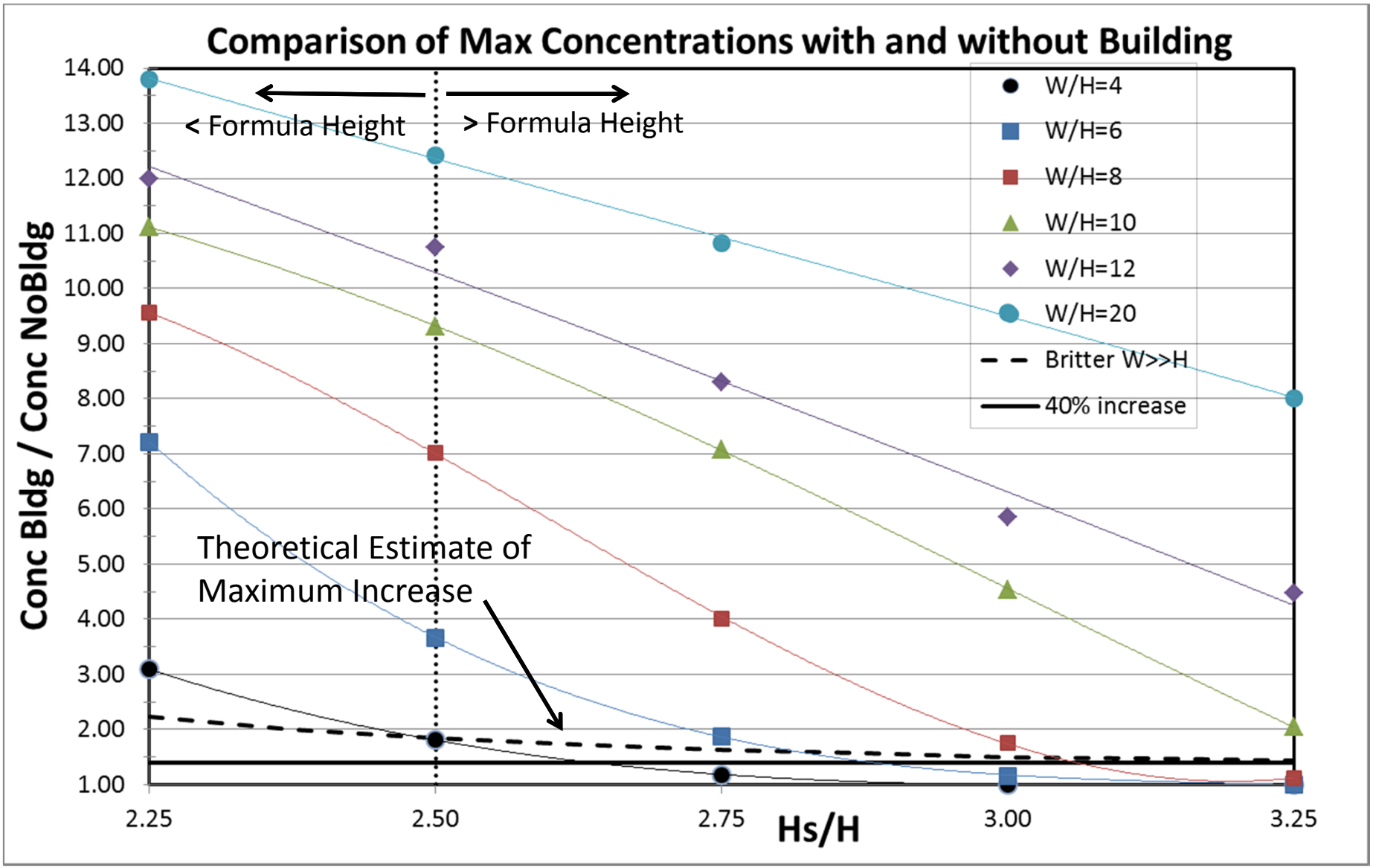
Evaluation Data	Max W/H
Bowline Point	2.1
Snyder WT	2.0
Thompson WT	2.0 to 4.0
Alaska North Slope	1.8
DAEC	1.2 to 4.4
Millstone	1.5 to 3.4
EOCR	1.4
AGA	2.8
Lee WT	1.3 to 3.9

Case Analysis to Illustrate Problem with Change to AERMOD

- Based on actual source; D=2.5m, w=20 m/s, T=350K, H=20m, W=220m, L=45m, W/H=11
  - Existing stack height above formula height but < 65m
- Examine stack heights up to 65m including above and below GEP formula height (50m)
  - H_S/H varied between 2.25 and 3.25
- Vary width between 10m-400m (W/H=0.5 to 20)
- One year simulation



Ratio of max concentrations with and without buildings are all below the 40% increase for stack heights ≥ formula height and W/H ≤ 3



Ratio of max concentrations with and without buildings are mostly above the theoretical estimate of increase for stack heights ≥ formula height and W/H ≥ 6; Before code change the ratio would have been 1 for stacks ≥ formula height

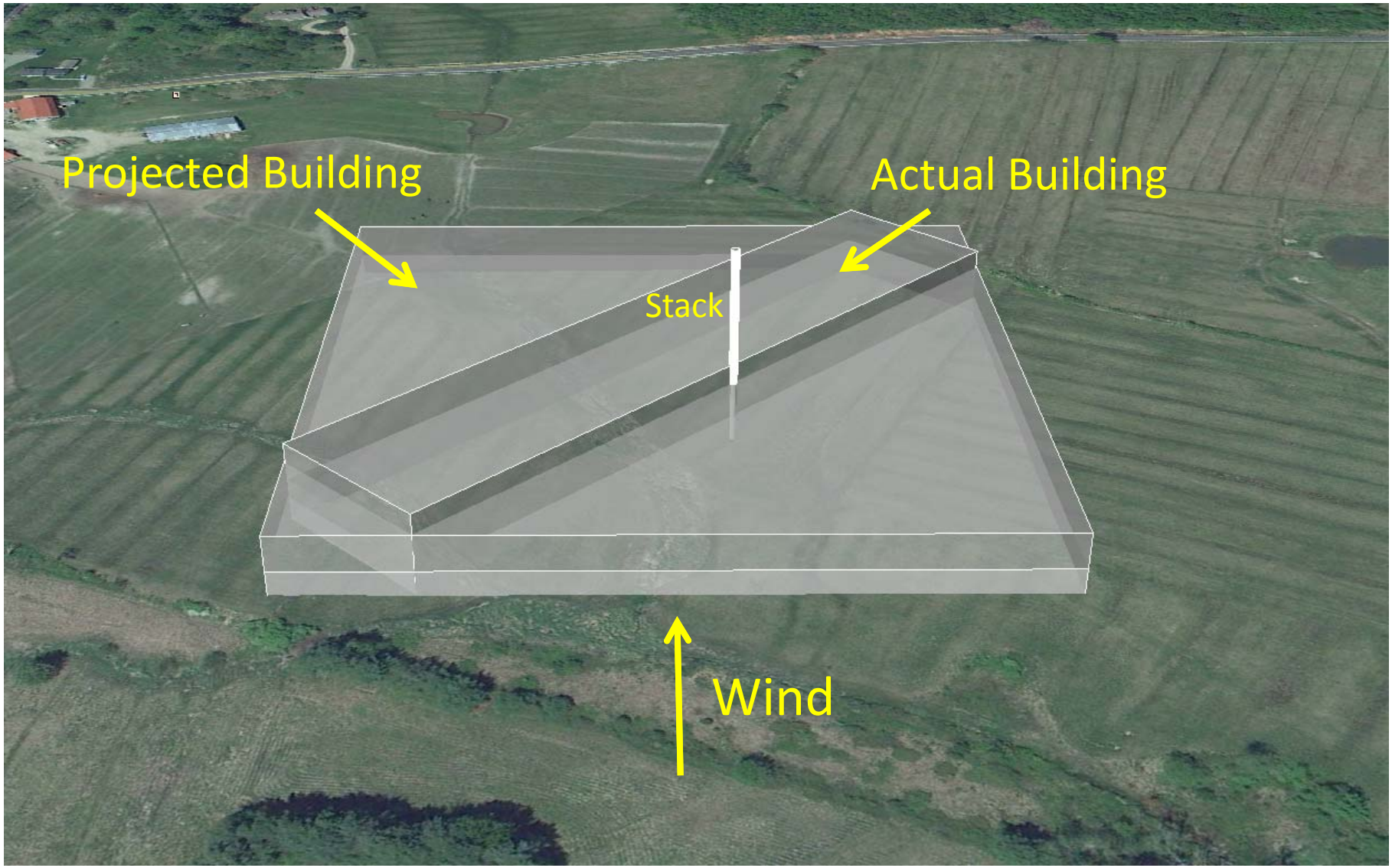
EPA Research on W/H Effects

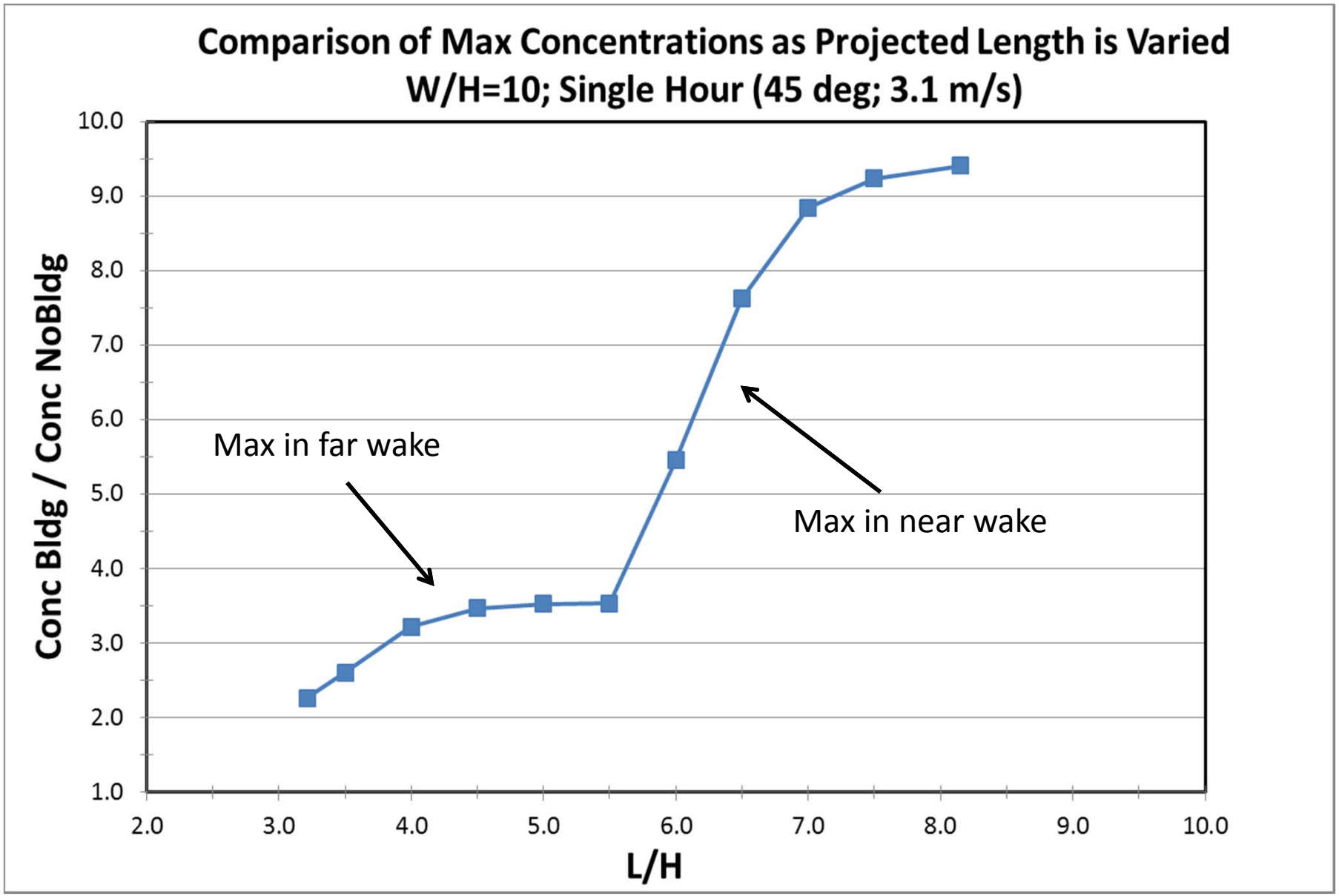
- Guideline for Determination of GEP Stack Height (Revised), June 1985
  - "…higher concentrations downwind of buildings depend quite strongly on building width."
  - "...maximum ground-level concentrations downwind of building structures should not be increased by more than 40 to 80 percent if the stack is equal to 2.5 times the building height."
  - The theoretical estimate (Britter et al., 1976) assumes W>>H and provides an upper estimate (85% increase at $H_S/H=2.5$ and 50% increase at $H_S/H=3$)

EPA Research on W/H Effects

- Huber (1989):The Influence of Building Width and Orientation on Plume Dispersion in the Wake of a Building, *Atm. Env.*, ***23***, 2109-2116
  - W/H ranging from 2 to 22
  - For elevated source (H_S/H=1.5), max GLC increased by factor of 2 for 45-60° wind angle (W/H=2)
  - As W/H increased to 4 and 8, max GLC <u>decreased</u>
  - Increases in W/H >8 <u>had little effect</u> on max GLC

BPIPPRM Projected Dimensions: Case Analysis
W/H=10, WD=45°, H_s/H=2.5



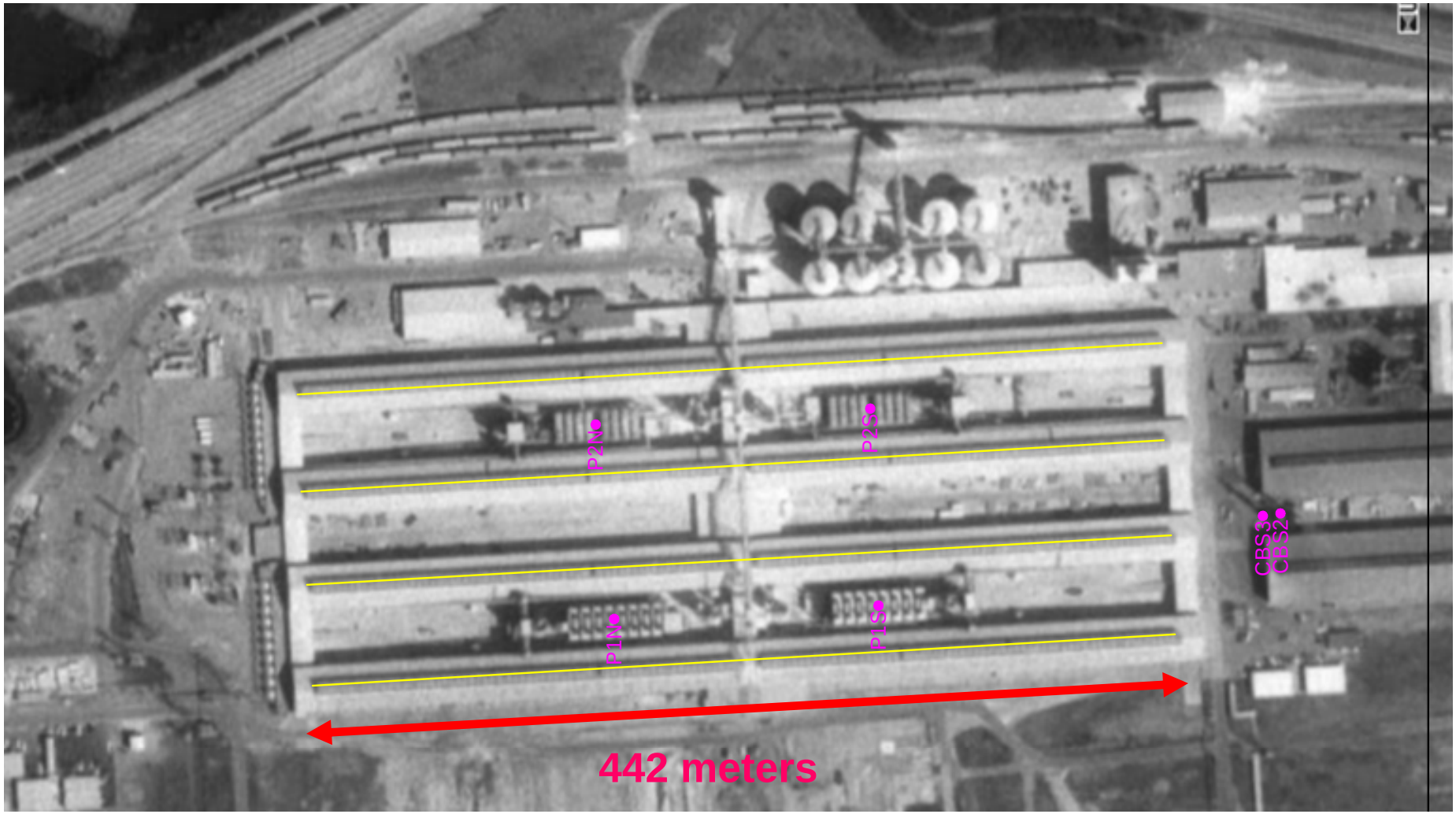


As projected length increases, more of the plume is predicted to be captured by the downwind cavity and max concentrations move from far wake to near wake

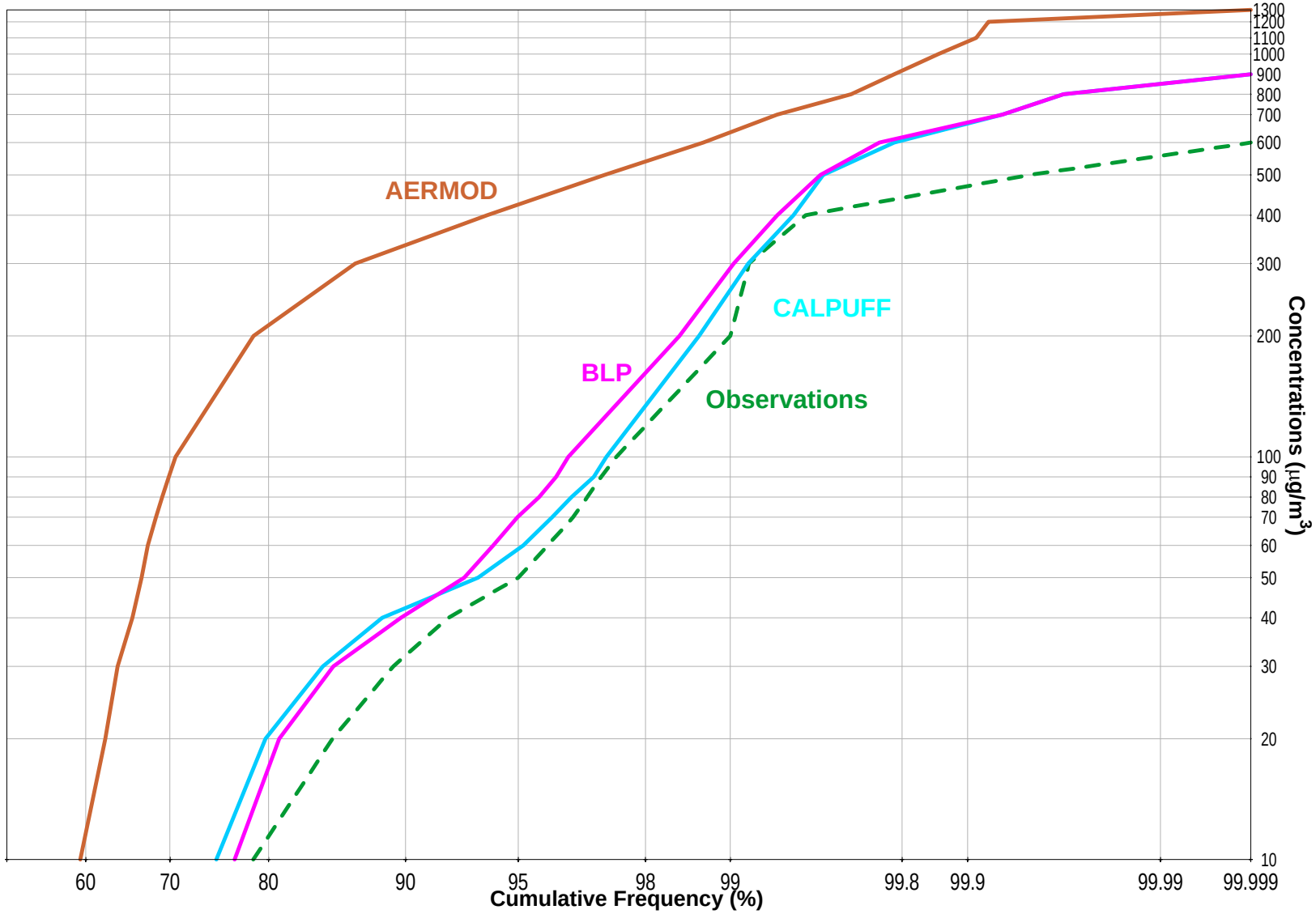
SO_2 Evaluation – Tennessee Smelter

- SO_2 measured upwind and 300m downwind of facility
- Primary sources: 4 potrooms (line sources), 4 banks of scrubber stacks (point sources)
  - Point sources ~ 93% of SO_2 emissions
  - Line sources ~ 7% of SO_2 emissions
- Two years of data evaluated as part of 1981 BLP evaluation which resulted in BLP acceptance as a *Guideline Model*
- Simulations with BLP, AERMOD and CALPUFF

Alcoa Tennessee Potrooms and Stacks



Observed v. Predicted Q-Q Plots – 1977 (1-hr Average SO_2 Concentrations)



Maximum Annual SO_2 Concentrations Observed and Predicted – Alcoa TN

Units: ($\mu g/m^3$)	**1976**	**1977**
Observed	8	13
CALPUFF	15.8	18.5
BLP	17.1	19.6
AERMOD	116.2	114.2

SO_2 Evaluation Findings

- AERMOD significantly over-predicted building downwash impacts of point sources (stacks) for very wide buildings
  - Potroom W/H of 10 – 25 are common
  - Over-prediction of observations by a factor of 10 or more on annual averages
  - Over-prediction of observations of factor of 2-10 on short-term (1-hr) averages
- BLP algorithms (in BLP or CALPUFF) perform well relative to observations
- EPA should allow Section 3.2 Petitions (use of alternative models) for this type of application

Questions?

- If formula height or a fluid modeling study (40% increase) is used to define GEP height, AERMOD could still predict an order of magnitude increase at that stack height
- Should stack height credit for modeling be defined by AERMOD or by GEP rules?
- Are we trading one discontinuity for another?

Conclusions

- Change to downwash procedures in AERMOD are significant
  - Case study showed seven-fold increase for W/H=8 and 12-fold increase for W/H= 20 at $H_S/H=2.5$
- Predicted building influences are inconsistent with theoretical estimates and wind tunnel studies
  - 85% increase at $H_S/H=2.5$
- No public peer review or comment on these changes; a clarification memo is not sufficient

Recommendations

- The change to downwash procedures should be removed from the regulatory version of AERMOD until independent peer review, consequence analyses, and evaluations are conducted for stacks above formula height
- These evaluations should be bundled with the independent review and evaluation of the effective length parameter in BPIPPRM