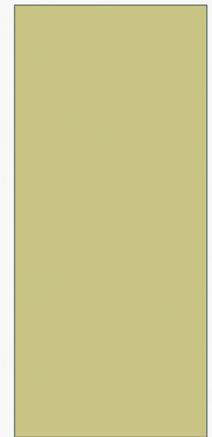


BOULEVARD TREE FAILURES
DURING WIND-LOADING EVENTS:
JUNE 21, 2013...A CASE STUDY

A REPORT TO THE MINNEAPOLIS CITY
COUNCIL FEBRUARY 3, 2015



UNIVERSITY OF MINNESOTA
DEPARTMENT OF FOREST
RESOURCES

GARY JOHNSON – PRINCIPLE INVESTIGATOR

TREES AND WINDS COLLIDE
EVERYWHERE

MOST SURVIVE OUTSIDE OF DIRECT PATHS OF DESTRUCTIVE WINDS



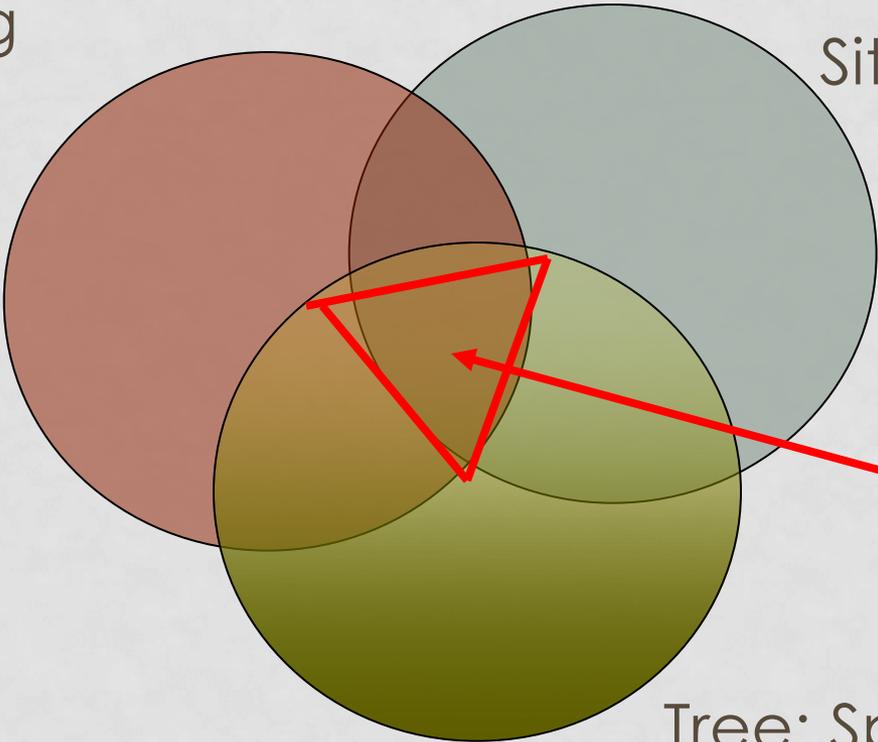
Photo: Ben Johnson

WHY DON'T ALL TREES FAIL?

THE FAILURE TRIANGLE

Loading
Event

Site Characteristics



**Storm Failure
Triangle**

Tree: Species,
Condition and
Defects

WIND LOADING EVENTS

- Thunderstorms – 25-80 mph
- Sustained winds – 40 mph or less
- Gusts – 60 mph or less
- Straight-line winds – 55+ mph
- Tornadoes – 40+ mph



SITE CHARACTERISTICS

- Degree of Friction
- Limited Root Plate
- High Water Table
- Shallow Soil Profile
- Degree of Disturbance



THE TREE

- Canopy Density
- Size
- Decurrent vs Excurrent
- Weight Displacement



MINNESOTA - JUNE 21, 2013

- Storms Began in Western Minnesota
- 85 m.p.h. Winds West of Metro
- Thunderstorm in a.m.
- 45 m.p.h. Winds in Metro
- 2.5" Rain in p.m.
- 2nd Storm in Early Evening
- <70 m.p.h. Winds in Metro



Photo: S. Stiteler

MINNEAPOLIS BOULEVARD TREE FAILURE STUDY

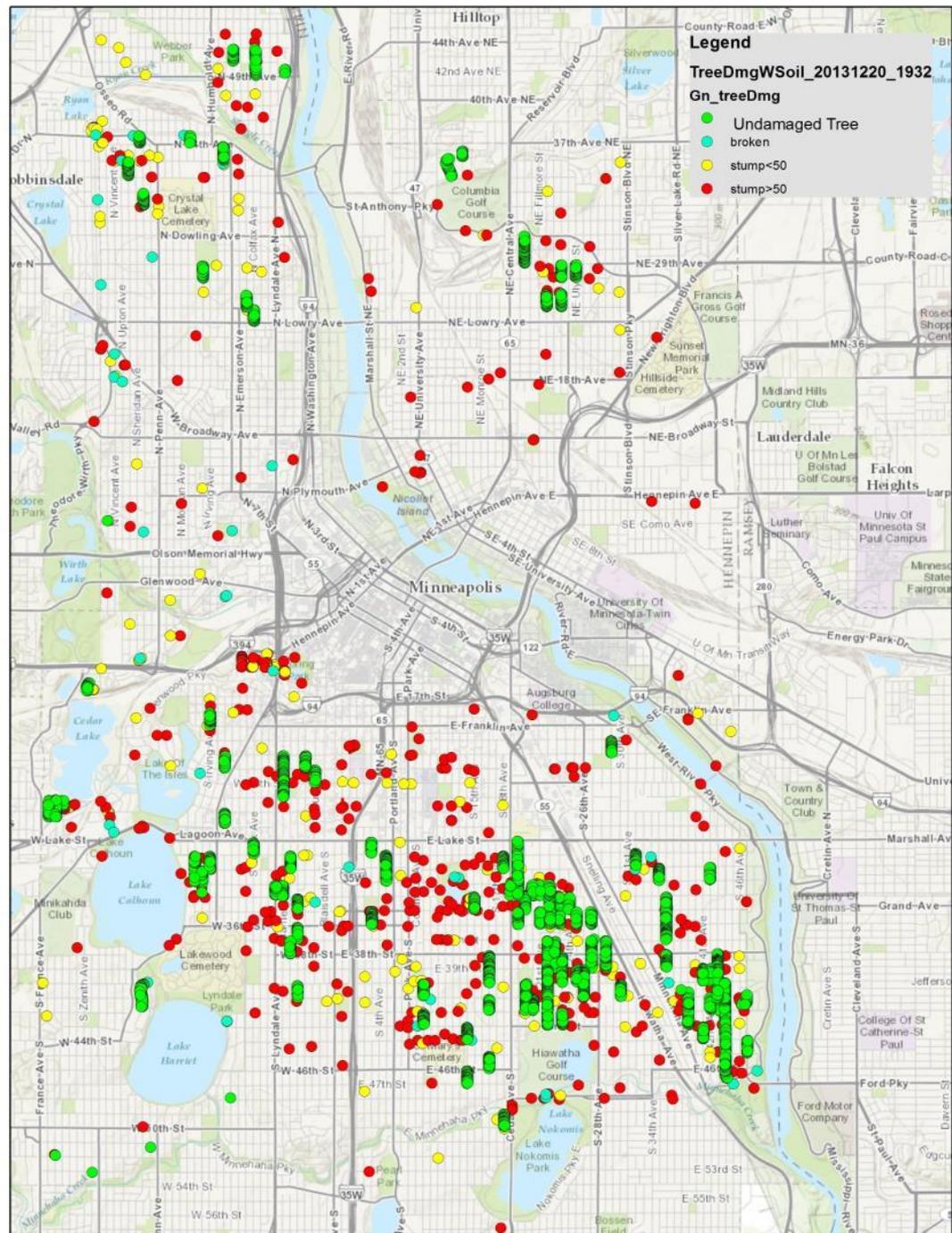
- Limited to Boulevard Trees
- Damage Limited to Tip-overs or Partial Tips
- Only Trees in Path of Storm



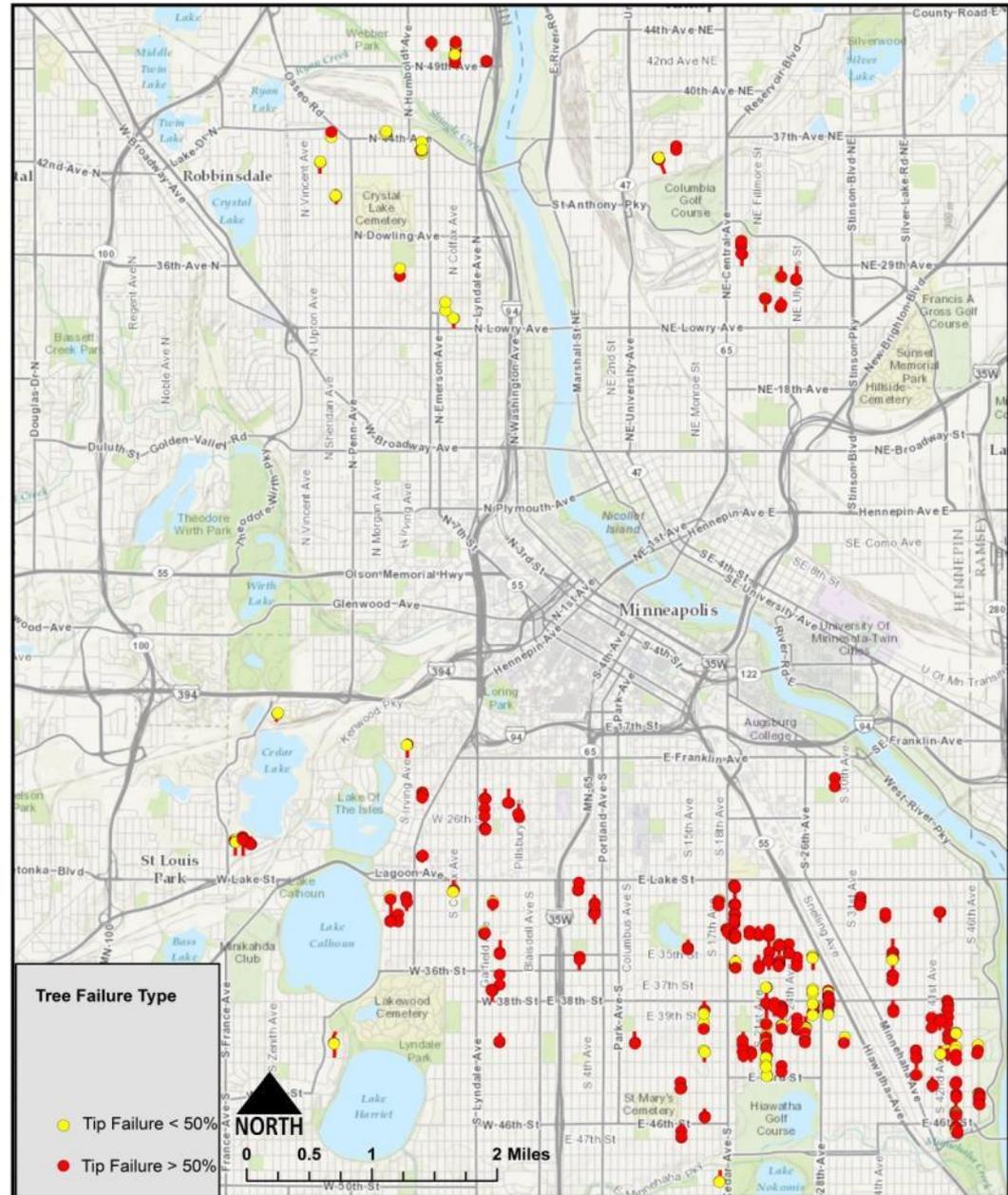
RESEARCH DESIGN

- Research Design by University of Minnesota Department of Statistics, Statistical Consulting Center (UMN/SCC)
- Sampling Units (122) were North/South Block Street Segments (**BSS**)
- A BSS Had Two (2) or More Tipped or Partially Tipped Trees (367 Tipped Trees)
- All Trees on All BSS Were Assessed (3,076 Trees Total)
- All Statistical Analyses Conducted by UMN/SCC

Winds and
Damage
Followed a
Path from
Northwest
Minneapolis
to Southeast
Minneapolis



FULL AND
PARTIAL
TIP
FAILURES
(367)



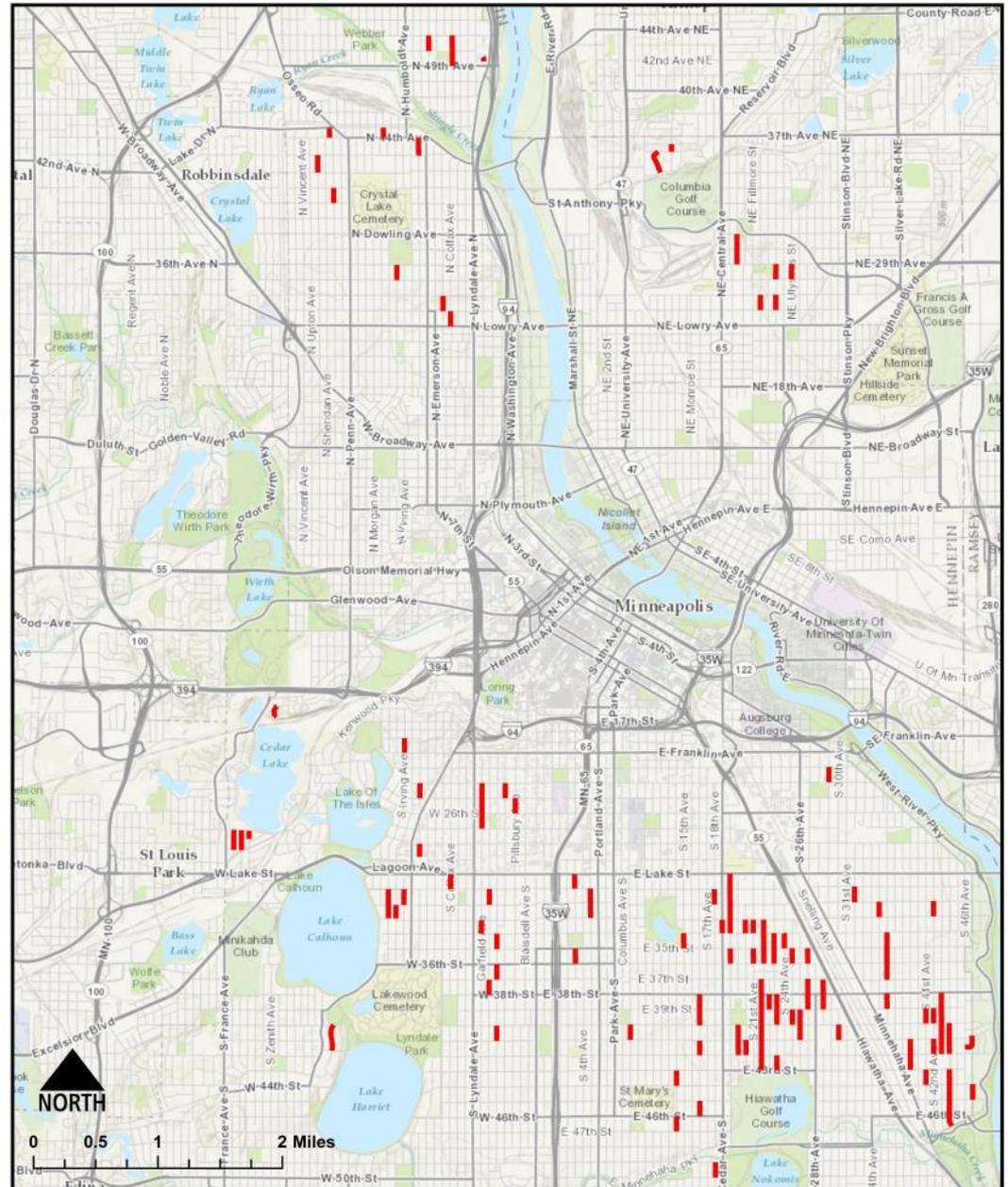
TIPS/PARTIAL TIPS

Greater Than 50%



Less Than 50%

BLOCK
STREET
SEGMENTS
(BSS) AS
SAMPLING
UNITS (122)



BLOCK STREET SEGMENT



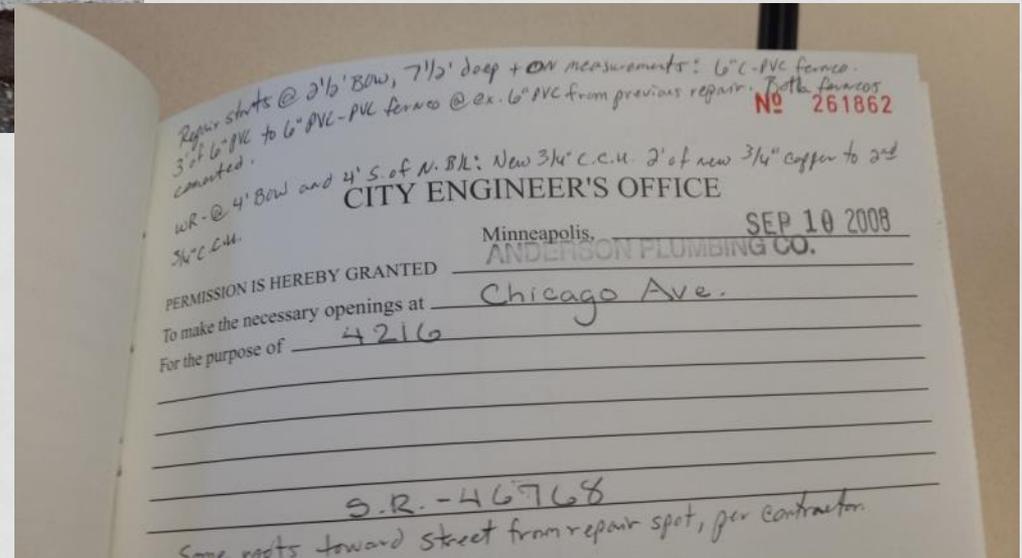
VARIABLES STUDIED

- Species
- DBH
- Boulevard Width
- Sidewalk Replacement w/in 5 Years
- Curb Replacement w/in 5 Years
- Damage to Curb and/or Sidewalk
- Stem Girdling Roots and Extent
- Soil Texture
- Soil pH
- Soil Compaction @ 6" and 12" Depths

SIDEWALK OR CURB REPLACEMENT



SIDEWALK OR CURB REPLACEMENT



DAMAGE TO CURB OR SIDEWALK



DAMAGE TO CURBS OR SIDEWALKS



RESULTS: SIDEWALK REPLACEMENT

- The major finding is that **having replacement work done increased the odds of root failure by 2.24 times** (95% CI: 1.77, 2.83; $p < 0.0001$).
- For illustration, when no replacement work was done, the average Tilia had a 10.6% chance of root failure; this increased to 21.0% when replacement work was done.



RESULTS: SIDEWALK REPLACEMENT

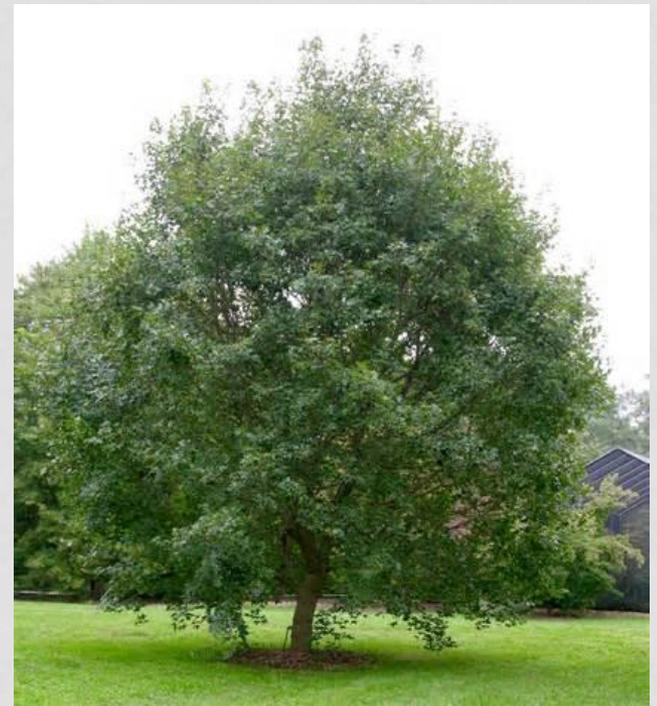


RESULT: SPECIES

*Tree species, when combined with replacement work, was also significant, with Tilia most likely to fail, followed by Fraxinus (ash), Acer (maple) and Ulmus (elm) in order. Essentially, **when sidewalk replacement work was done near any one of these trees, the rate of failures more than doubled (p=.0001)***

RESULTS: SPECIES

1. **Littleleaf Linden Most Likely to Fail**
2. **Green Ash**
3. **Maples**
4. **Elms**
5. **Others**



RESULTS: D.B.H.

*Tree size, measured as trunk diameter (DBH), was significantly related to failure rates, with **larger tree diameters more likely to fail (p=.008) independent of whether sidewalk replacement work was conducted.***



RESULTS: BOULEVARD WIDTH

Boulevard width was significantly related to tree failures ($p=.011$) only when sidewalk replacement work was conducted. For example, a *Tilia* in a boulevard four (4) feet wide that had experienced sidewalk replacement damage to its root system had a failure rate of 29.4%. The same tree in an eight (8) foot wide boulevard had a failure rate of 14.6%.

RESULTS: BOULEVARD WIDTH



RESULTS: SOIL PROPERTIES

- Soil pH: no correlation
- Soil % Sand: no correlation
- Soil % Silt: no correlation
- Soil % Clay: no correlation
- Soil Organic Matter: no correlation
- Soil Compaction: Compaction at 6" Correlated with Tree Failure **Only When Sidewalk Replacement was Done... $p=.019$**

TAKE-HOME RECOMMENDATIONS

1. Cutting Roots Jeopardizes Stability.
2. Consult with Foresters/Horticulturists/Arborists.
3. Wider is Better...for Boulevards.
4. Larger Trees Need Larger Boulevards.

FUNDING FOR THIS STUDY PROVIDED BY:

- Minneapolis Park and Recreation Board
- Mississippi Watershed Management Organization
- University of Minnesota – Urban Forestry Outreach, Research and Extension Laboratory

ACKNOWLEDGEMENTS

- City of Minneapolis, Department of Public Works:
 - Steve Collins
 - Dan Bauer
 - Brad Blackhawk
 - Jim Glenn
 - Jeff S. Handeland
 -
- Minneapolis Park and Recreation Board, Forestry Department:
 - Ralph Sievert
 - Philip Potyondy
 - Mary Berthiaume O'Neill
 - Bryan Frazier
 - Jim Spencer
 -
- University of Minnesota, School of Statistics:
 - Aaron Rendahl, Statistical Consulting Manager