Kalotay Analytics

A DIVISION OF ANDREW KALOTAY ASSOCIATES, INC.

Creating a Live Yield Curve In the Illiquid Muni Market

- Andrew Kalotay -

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61 Broadway New York, NY 10006 212.482.0900 www.kalotay.com

Real-Time US Treasury Yields

Source: Bloomberg

Real-Time UST Yield Curve

Source: Bloomberg

How About the Muni Market?

Large but illiquid

- Small issue sizes, little trading after issuance
- Trades reported within 15 minutes to regulator MSRB/EMMA

Common structure: Serial issue of 5% bonds, callable at par after 10 years (5% NC-10)

- Issued at a significant premium

No live yield curve

- Although needed for a wide range of purposes

Typical Recent Municipal Issue

$78,265,000
STATE OF OREGON
OREGON FACILITIES AUTHORITY
REVENUE REFUNDING BONDS
(Samaritan Health Services Project)
2016 Series A

Maturity Schedule

Yield-to-Worst

Maturity Date (October 1)	Principal Amount	Interest Rates	Yield	Price	CUSIP†
2024	$1,155,000	5.000%	2.280%	119.503	68608JVU2
2025	1,440,000	5.000	2.560	119.258	68608JVV0
2026	3,580,000	5.000	2.720	119.625	68608JVW8
2027	3,775,000	5.000	2.870	118.199*	68608JVX6
2028	3,965,000	5.000	2.970	117.260*	68608JVY4
2029	1,885,000	5.000	3.050	116.515*	68608JVZ1
2030	1,975,000	5.000	3.130	115.776*	68608JWA5
2031	7,430,000	5.000	3.200	115.133*	68608JWB3
2032	7,970,000	5.000	3.260	114.586*	68608JWC1
2036	1,095,000	5.000	3.390	113.411*	68608JWG2

$19,685,000, 5.000% Term Bonds due October 1, 2035, Yield 3.380%, Price 113.501*, CUSIP†68608JWF4

$7,800,000, 5.000% Term Bonds due October 1, 2041, Yield 3.500%, Price 112.428*, CUSIP†68608JWH0

$16,510,000, 5.000% Term Bonds due October 1, 2046, Yield 3.530%, Price 112.162*, CUSIP†68608JWJ6

* Priced to the first optional call date of October 1, 2026.

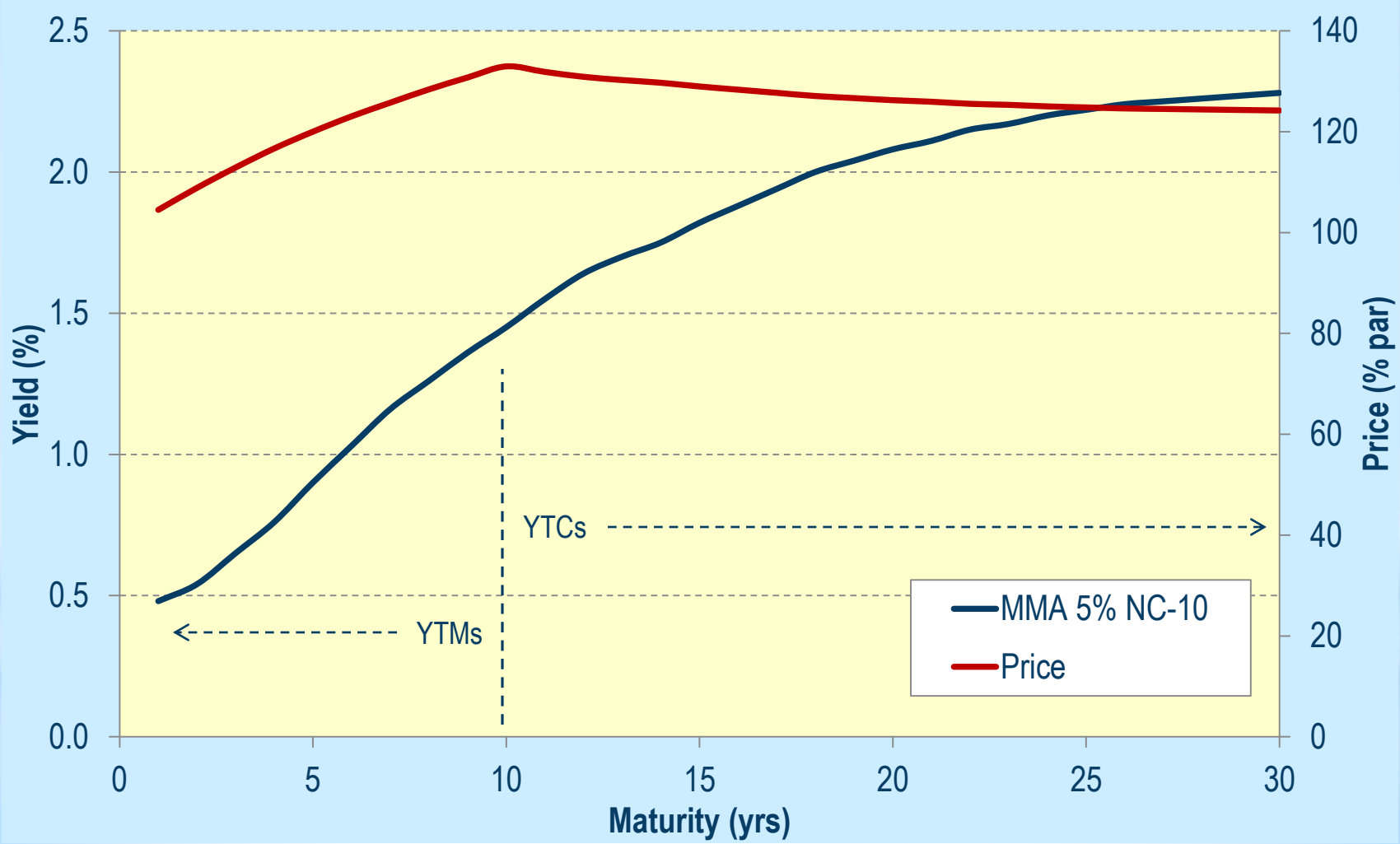
Why 5% NC-10?

- Issuers: Show large savings from refunding
  - Call option at issuance is deep in the money
  - Bonds are usually eligible for advance refunding
- Institutional investors: Avoid undesirable mark-to-market treatment if rates rise
  - Prices of bonds selling at a discount are further depressed by tax payable at maturity by marginal buyer
    - Bonds issued at a high premium are unlikely to fall below par

Benchmark Curves Represent Yields of 5% NC-10 Bonds

- Because 5% NC-10 is the standard structure
  - Used to be par NC-10
- Curves distributed by several vendors, once or twice daily
  - MMA and MMD are best known
  - Bloomberg curve represents yields of 5% *optionless* bonds
- Yields obtained by surveying major market participants and using trade data from EMMA
  - Process not transparent

Typical 5% NC-10 Yield Curve
And Corresponding Prices



Problems with Callable Benchmark Curves

Fail to be arbitrage free: *Prices of 5% callable bonds should decline with maturity*

- Increasing yields do not assure declining prices

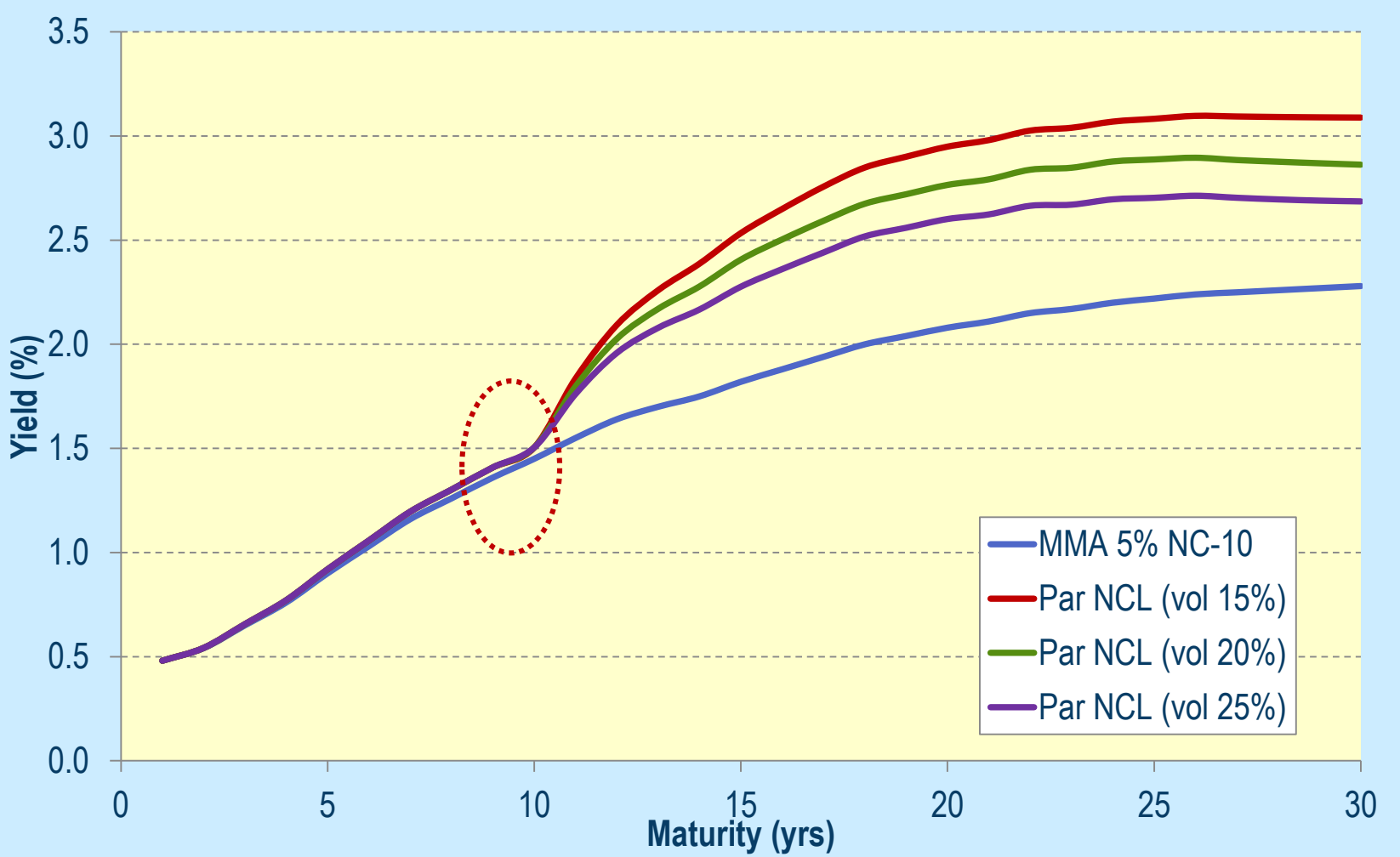
Implied optionless (NCL) curve not credible: Smooth callable curve implies *kink in optionless curve*

Usage: Analysts fail to 'strip out' call option

- Should use optionless curve
- Results based on callable benchmark are misleading

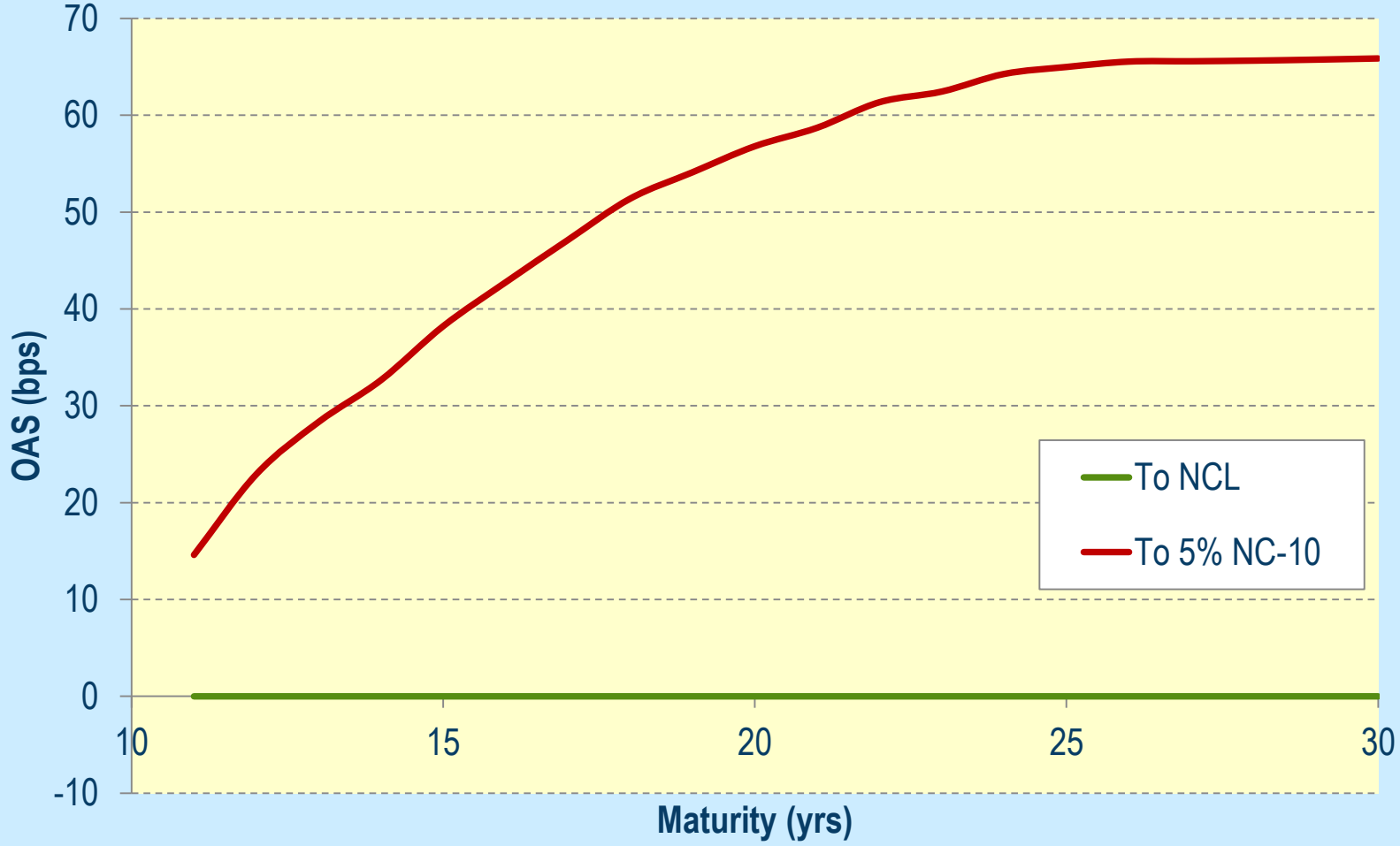
Examples follow

Smooth Callable Curve Implies Kink in Optionless Curve



Smooth Optionless Curve Implies Kink In Callable Curve

Spreads of Benchmark Bonds to Callable Curve Are Nonsensical



The AP/MBIS Yield Curves

- Benchmark curve derived from ‘ask’ prices posted by several dealers for roughly 4,000 investment-grade bonds
  - Bonds updated monthly
  - Selection, prices, and curve construction fully documented
  - Rigorous, automated process; uses CurviLinear™ methodology
- Credit-specific and optionless curves also reported
- Calculated and disseminated hourly
  - Plans call for greater frequency
- Distributed to financial institutions, the press, and to the public (by AP, via third party tools)

CurviLinear™ Methodology

❶ Solve for *optionless par yield* curve that prices bonds as closely as possible to the input prices

- Multidimensional nonlinear regression using Google's open source Ceres Solver

❷ Derive 5% NC10 curve from optionless par curve

- YTW's of fairly priced 5% NC10 bonds

All prices, including call option values, computed using standard bond analytics (Black-Karasinski process with 15% vol, tax-neutral OAS)

Work in progress:

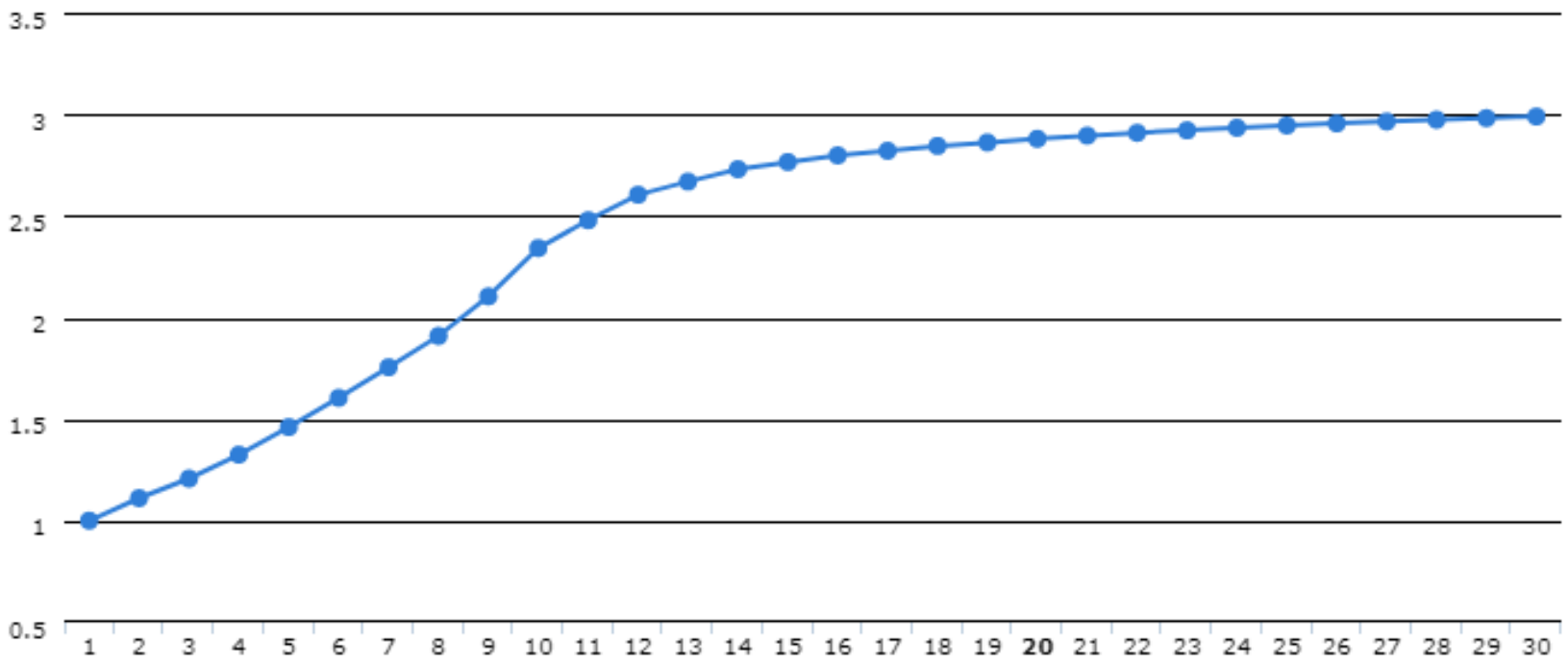
- Improve fit by solving for par curve and volatility simultaneously
- Build volatility surface – by maturity and lock-out
  - E.g. Vol of 5% bond maturing in 15 years callable in 8 years is 17.3%

AP Municipal Benchmark Curve

Powered by MBIS and Kalotay Analytics

Date: 07/06/2017 Curve: Benchmark Rates as of 01:00 PM

AP Tax Exempt Municipal Benchmark Yields

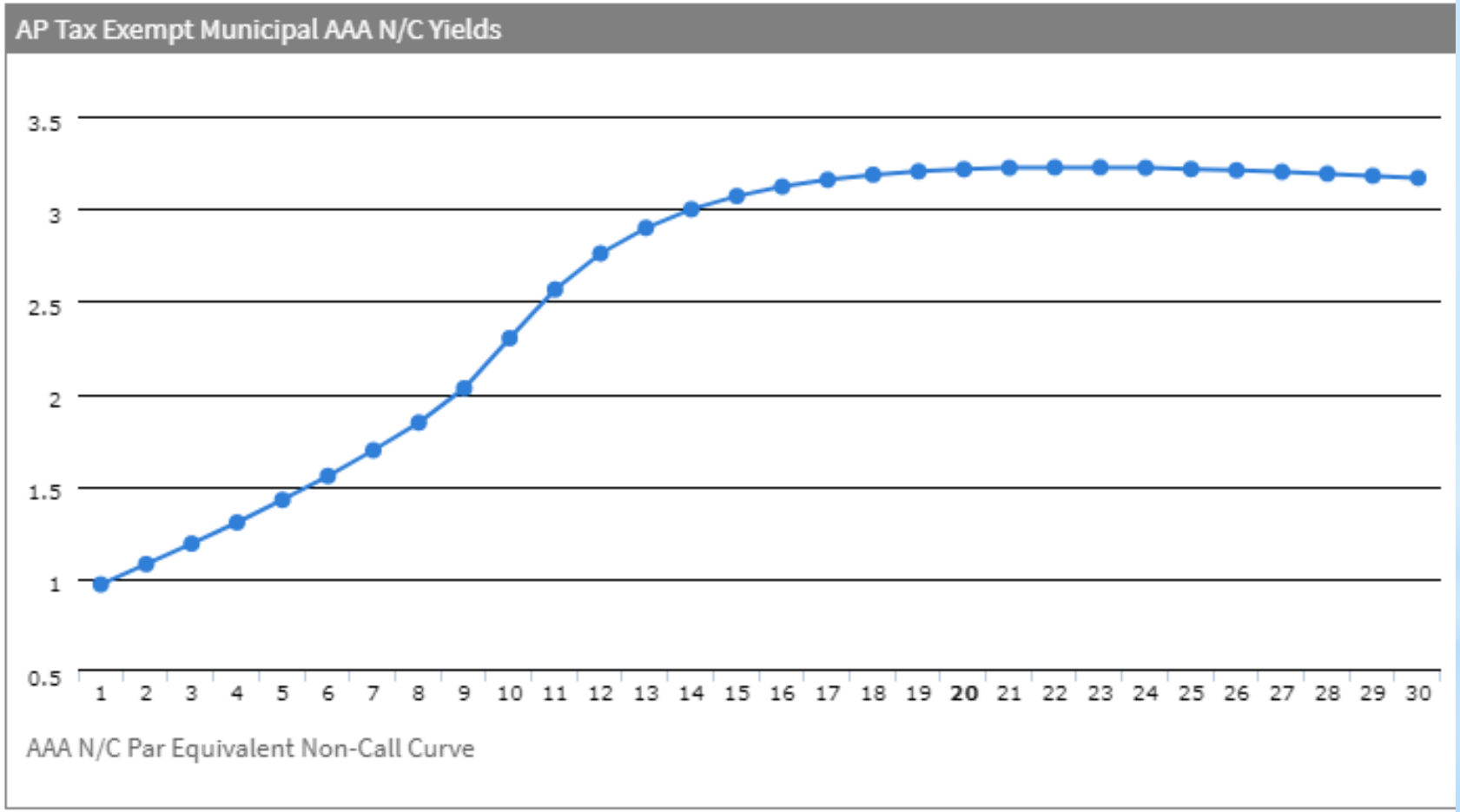


Benchmark 5% Non-Call 10yr Curve

Municipal AAA N/C Curve

Powered by MBIS and Kalotay Analytics

Date: 07/06/2017 Curve: AAA N/C Rates as of 01:00 PM



In Summary

- Muni market has lacked a live benchmark yield curve
- Standard curves represent yields of hypothetical 5% callable bonds
  - Opaque process, often defective and misused
- New AP/MBIS curves are derived from ask prices of selected bonds across maturity spectrum
  - Methodology transparent
  - Currently updated hourly
  - Approach allows for ongoing enhancements
    - More frequent updates
    - Interest rate volatility surface

Contact Information

Andrew Kalotay

andy@kalotay.com

(212) 482 0900