Evaluating Best-Practice Capacities for a Carbonate Island Karst Aquifer: Northern Guam Lens Aquifer, Guam, USA

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Overview

1. Background
   - Previous work & objectives of this project
2. Sustainability definitions
   - Natural resource extraction concepts
3. The Northern Guam Lens Aquifer
   - Aquifer hydrogeology; production system layout
4. Imagineering the "perfect" system
   - Real vs. simulated performance
5. Conclusion – emerging insights

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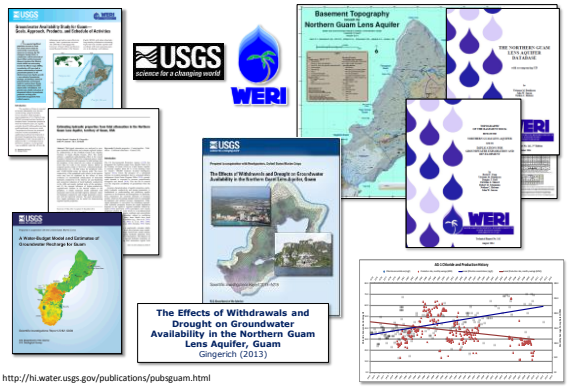
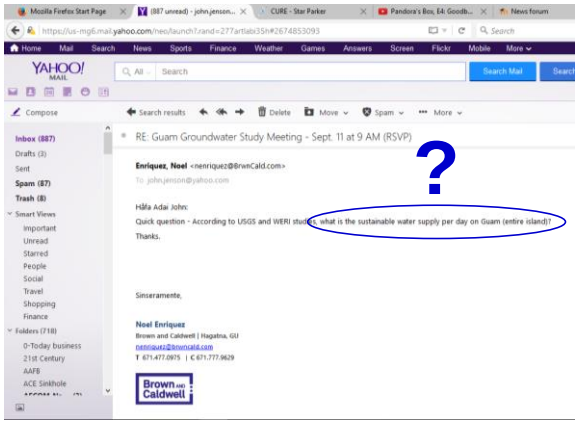
Previous Works – 2010 to 2013



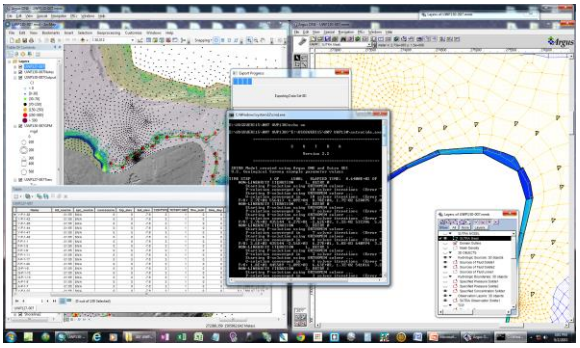
http://hi.water.usgs.gov/publications/pubsguam.html



Study Plan

- Concept design: Phase 1, 2014-2015
  - Development and design of conceptual model
- Implementation: Phase 2, 2015-2016
  - Configuration and testing of model
- Application: Phase 3, 2016-2017
  - Numerical simulations with model
    - Basin-by basin evaluation: assay curves
    - Takin' it to the limit—one more time….
      - More wells, higher pumping rates

Phase 2, Implementation: Reconfiguration of USGS 2010-2013 Model (Gingerich, 2013)



The Objective

"Ultimate Theoretical Capacity"

(Jenson, Habana & Gingerich in prep.)

"The potential capacity that *could* be achieved by an *ideal* production system, given perfect knowledge of the natural limiting conditions"

Requires identifying:

The natural limits imposed by aquifer recharge and geology

An ideal production system, i.e.,
one utilizing the best available technology
to deliver maximum extraction
while maintaining a given quality standard

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Sustainable Yield

Has always been a slippery concept…

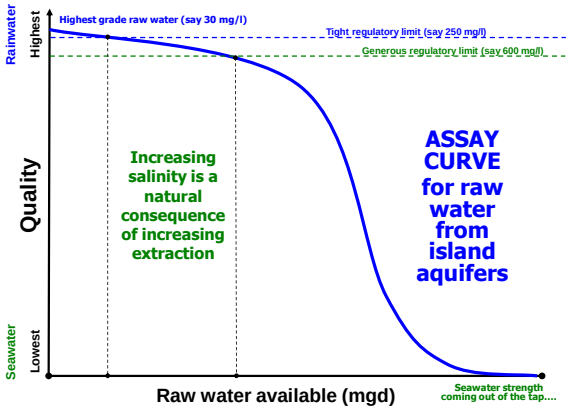
Sustainable Yield (Mink 1982)

"The rate of production that can be sustained without unacceptably degrading water quality"

- Expressed as a percent of recharge (20-25%)
- Relied on professional judgement
- Entirely subjective

Extraction

Refined Product = Drinking Water
1. Potable fresh water (non-saline)
2. Safe to drink
3. Tastes, smells, looks good
4. Delivered to your tap 24/7
5. Under sufficient pressure



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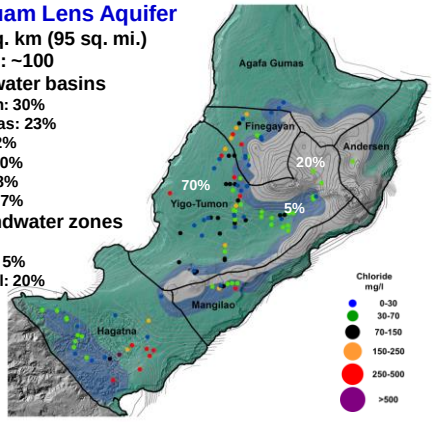
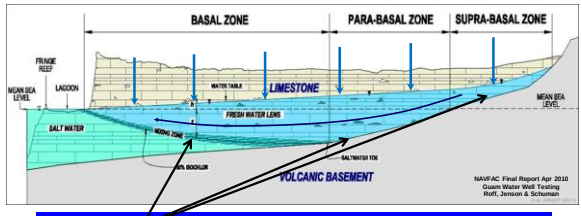
Northern Guam Lens Aquifer

- Area: 264 sq. km (95 sq. mi.)
- Active wells: ~100
- Six groundwater basins
  - Yigo-Tumon: 30%
  - Agafa Gumas: 23%
  - Hagåtña: 22%
  - Mangilao: 10%
  - Andersen: 8%
  - Finegayan: 7%
- Three groundwater zones
  - Basal: 70%
  - Para-basal: 5%
  - Supra-basal: 20%
- Recharge
  - 255 MGD
    - 65"/yr
  - 200 MGD
    - 51"/yr



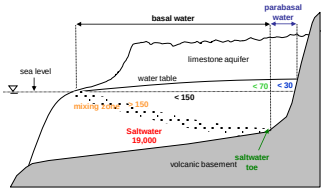
Groundwater Zones



- Supra-basal water: underlain by basement rock and stands above sea level
  - Invulnerable to sea water contamination
  - Very high quality water—headwaters of the catchment
  - Most responsive to wet-dry cycles
  - Very hard to find (even with a map; occurs in patches)

Groundwater Quality

Chloride Benchmarks



CDM (Mink), 1982
McDonald & Jenson, 2003

parabasal range	≤ 30 mg/l
saltwater toe range	> 30 to 70 mg/l
basal range	> 70 to < 150 mg/l
saltwater intrusion	≥ 150 mg/l
USEPA standard	250 mg/l

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Imagineered Conditions

1. Quality target <150 mg/L chloride
   - Same as sought by Mink (1982)
2. Current technology of choice
   - vertical wells, 25 ft deep
3. Capped extraction at 500 gpm each well
4. About same number of wells as present
5. Assigned all wells to the para-basal zone
   - Suspended access considerations

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The Maximum-Capacity (Imaginary) System

Takin' It to the Limit…!

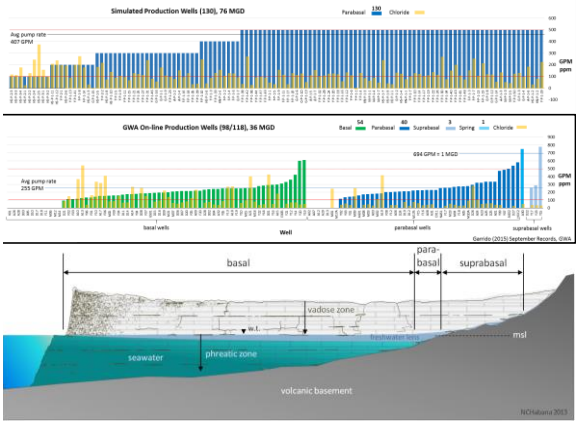
Actual vs. Simulated Systems	Actual*	Simulated
Number of wells	118**	130
No. of wells on line	98**	130
Depth of wells (ft)	mostly about 40	25
Pumping rates (gpm)	100-750	100-500
Basal wells	66	0
Para-basal wells	48	130
Supra-basal wells	3	0
Total production (MGD)	40***	76

*GWA only; Does not include ~14 DOD wells.
**includes 1 spring
***GWA + DOD production (36 + 4)

Actual System (GWA)

Recharge & Extraction by zone	Portion of aquifer	Recharge (MGD) by zone	Actual extraction (MGD) by zone*	Simulated extraction (MGD) by zone	Extraction as pecent of zonal recharge	
					Actual*	Simulated
Entire aquifer	1.00	200	36	76	18%	38%
Supra-basal zone	0.20	40	2	0	34%	100%
Para-basal zones**	0.05	10	15	58		
Basal zone	0.75	150	18	18	12%	12%

*GWA only; does not include DOD production.
**Interior rise and southern fault zone



Summary

Takin' It to the Limit…!

Total extraction: 76 MGD 38% of recharge

Not yet harvesting the outer basal zone

50 MGD extraction

18 MGD Extraction (basal)

68 MGD extraction

8 MGD extraction

50 MGD Supra-basal + para-basal recharge

for 200 MGD total recharge

Pumping rate gpm: 100, 200, 300, 400, 500

Chloride mg/l: 0-30, 30-70, 70-150, 150-250, 250-500, >500

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Exploring Ultimate Capacities of the Northern Guam Lens Aquifer

Sustainable Management (Ponce 2008)

Social, economic, and legal constraints also set limits

- **"It's about more than just hydrology"**
- **Some areas are off limits, or inaccessible**
- **Or too expensive to develop with current technology…**