WATER CHEMISTRY AND BREWING

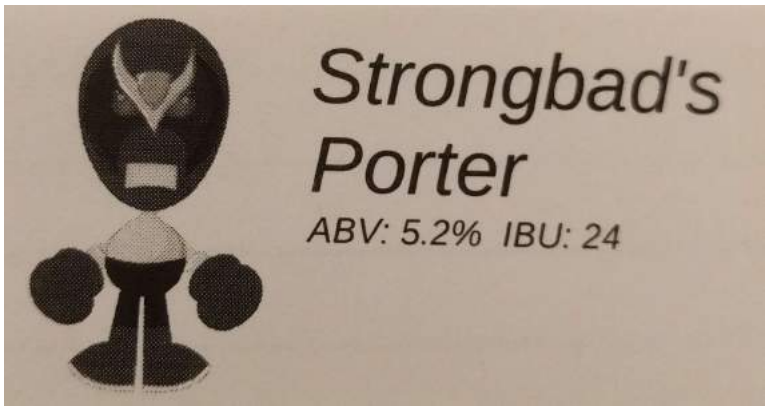
MHTG

(COLIN CROWLEY, TIM TAUTGES, WITH PLAGIARIZED PARTS FROM MARK GARTHWAITE)

WHY DO WE CARE ABOUT WATER?

- WATER – NOT MUCH - ONLY CARE ABOUT CONCENTRATION/DILUTION – ALTHOUGH IT DOES MATTER FOR MASH EFFICIENCY, HOP UTILIZATION, ETC.
- MINERALS IN WATER, HOWEVER, HAVE TWO MAIN IMPACTS
  - MASH (PART 1 OF TALK)
  - FLAVOR IMPACT IN FINAL BEER (PART 2 OF TALK)
  - EXPERIMENTAL SECTION (I.E. WORK IN PROGRESS) (PART 3 OF TALK)
    - MEADS
    - CIDERS
    - WINES
    - SOURS?

PART I: TIM'S STORY



PART I: TIM'S STORY

- EXTRACT BREWING: NO WORRIES!
- ALL-GRAIN BREWING
  - STARTED WITH DARK BEERS BECAUSE THAT'S WHAT I LIKE – NO WORRIES!
  - THEN I TRIED AN IPA – WORRY!
    - ORIGINAL GRAVITY WAS ABOUT 20 POINTS LOW AFTER MASHING – WHY???
    - LIKE OLD STYLE – IT'S THE WATER

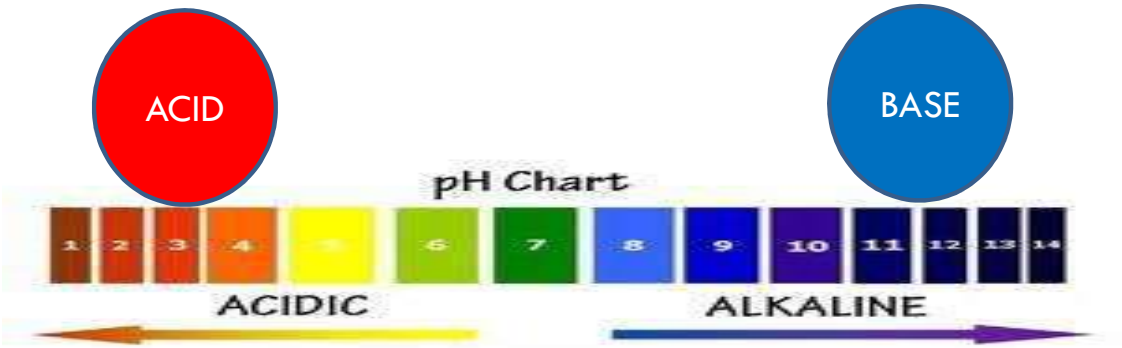
PART I: MASH EXPERIMENT

Water→ Beer type ↓	Tap	RO
IPA (light)	x	x
Stout (dark)	x	x

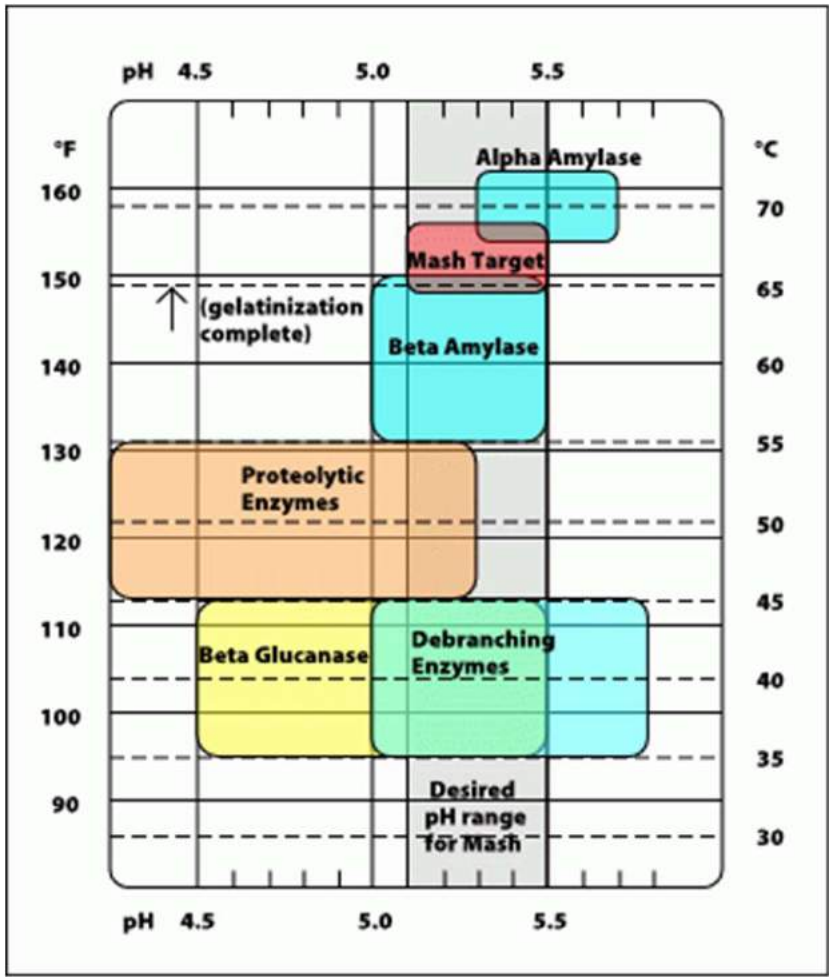
IPA	Stout
8 lbs Pale Malt (2 Row)	4 lbs 12.53 oz Pale Malt (Maris Otter) (69%)
10.31 oz Crystal 40 L	8.50 oz Biscuit Malt
	8.50 oz Chocolate Malt
	8.50 oz Roasted Barley
	8 oz Lactose
4.82 gallons water	4.65 gallons water
OG: 1.070	OG: 1.058

QUICK TERMS

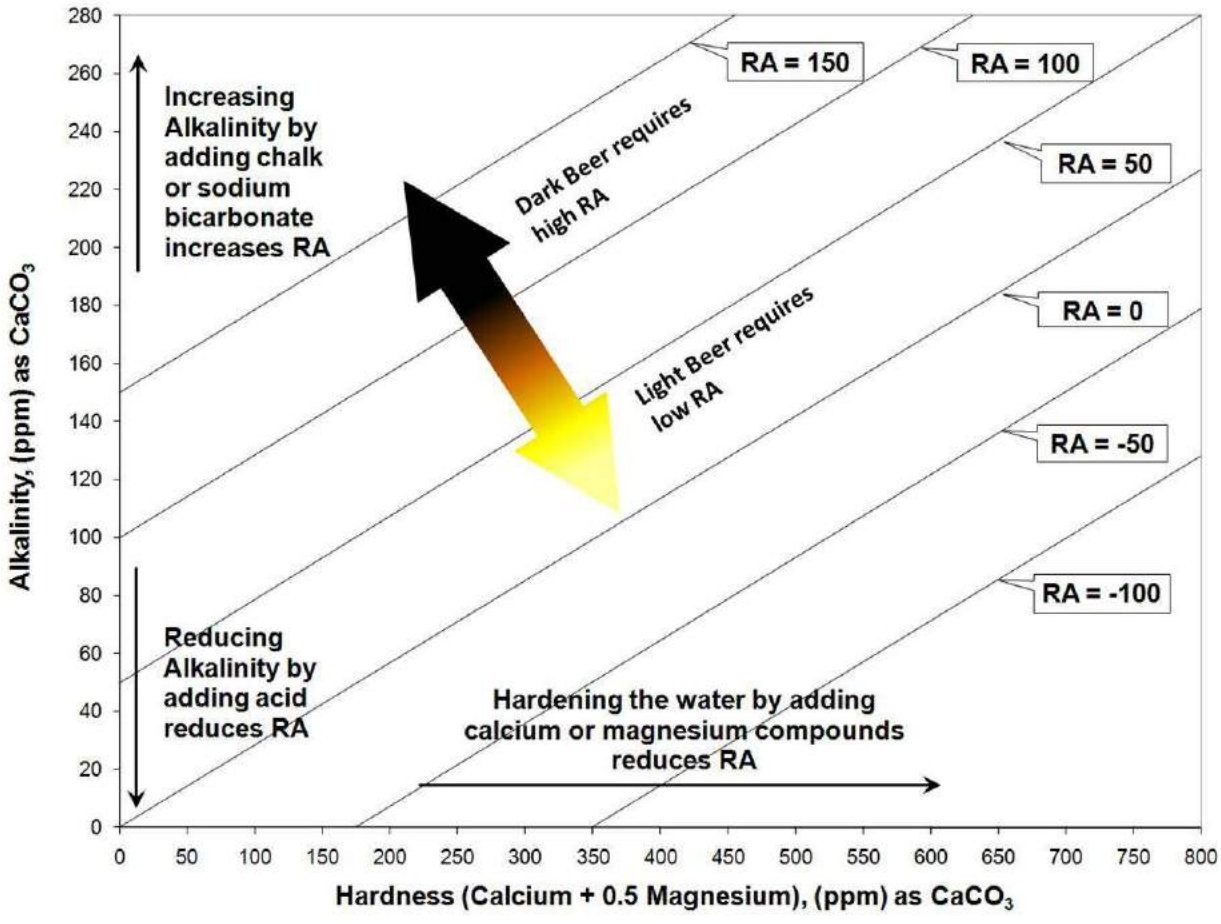
- PH – MEASURE OF HOW ACIDIC (LOW PH) OR ALKALINE (HIGH PH) SOMETHING IS
- TOTAL ACIDITY/ALKALINITY – HOW MUCH RESISTANCE THERE IS TO CHANGE PH



HOW DOES THIS AFFECT MASH?



DIFFERENT GRAINS HAVE DIFFERENT ACIDITY



HOW DO I DETERMINE MY WATER PROFILE

- MUNICIPAL REPORTS (https://www.cityofmadison.com/water/documents/ComprehensiveWaterQualityMonitoringReport.pdf)
  - AVAILABLE ONLINE
  - ANNUAL AND AQUIFIER AVERAGE
  - MORE CONCERNED WITH CONTAMINANTS THAN FLAVOR
  - LOTS OF DATA
  - FREE
- TEST WATER SAMPLE (https://www.wardlab.com/product/water-test-kit/)
  - TESTS FOR KEY BREWING MINERALS
  - TIME SNAPSHOT
  - $42-48 (CAN ADD ADDITIONAL TESTS)
  - TESTS YOUR SPECIFIC WATER SOURCE
- MEASURE WATER SAMPLES (https://www.lamotte.com/en/food-beverage/brewlab)
  - TESTS FOR KEY BREWING MINERALS
  - NOT AS COMPREHENSIVE/PRECISE AS WATER SAMPLE TESTING
  - CAN PERFORM MULTIPLE TESTS
  - YOU PERFORM THE TESTING
  - $126-217

LOCAL WATER PROFILES

	RO	Madison Hard Municipal Data	Madison Hard Lab Data	Madison Soft Calculated
Calcium	1	70	69.6	3
Magnesium	0	41	37	2
Sodium	8	9	9	151
Sulfate	1	21	4	21
Chloride	4	19	15	19
Bicarbonate	16	364	344	364
Alkalinity	13	302	283	302
Hardness	3	259	329	12

WARD Laboratories, Inc.

Ag Testing - Consulting

Account No. : 64731

Water Analysis Report

CROWLEY, COLIN
834 N BRISTOL ST
SUN PRAIRIE WI 53590

Invoice No. : 1316404
Date Received : 05/15/2020
Date Reported : 05/18/2020
Lab Number : 3684

Results For : COLIN CROWLEY
Location :
Sample ID :

pH	7.8
Total Dissolved Solids (TDS) Est, ppm	378
Electrical Conductivity, mmho/cm	0.63
Cations / Anions, me/L	7.0 / 6.4

	ppm
Sodium, Na	9
Potassium, K	1
Calcium, Ca	69.6
Magnesium, Mg	37
Total Hardness, $CaCO_3$	329
Nitrate, NO_3-N	1.7 (SAFE)
Sulfate, SO_4-S	4
Chloride, Cl	15
Carbonate, CO_3	< 1.0
Bicarbonate, HCO_3	344
Total Alkalinity, $CaCO_3$	283
Fluoride, F	0.68
Total Phosphorus, P	< 0.01
Total Iron, Fe	< 0.01

"<" - Not Detected / Below Detection Limit

Reviewed By : Nick Ward **5/19/2020** **Copy : 1** **Page 1 of 1**

Bus: 308-234-2418
Fax: 308-234-1940
web site
www.wardlab.com
4007 Cherry Ave., P.O. Box 788
Kearney, Nebraska 68848-0788

MASH PH RECOMMENDATIONS

	Recommended pH
Lighter Colored	5.3-5.4
Darker Colored	5.4-5.6
Tart or Crisp Styles	5.2-5.3

RECIPES LIGHT VS DARK

IPA	Stout
8 lbs Pale Malt (2 Row)	4 lbs 12.53 oz Pale Malt (Maris Otter) (69%)
10.31 oz Crystal 40 L	8.50 oz Biscuit Malt
	8.50 oz Chocolate Malt
	8.50 oz Roasted Barley
	8 oz Lactose
4.82 gallons water	4.65 gallons water
OG: 1.070	OG: 1.058

MASH PH - LIGHT VS DARK

	IPA	Stout
Recommended Mash pH	5.3-5.4	5.4-5.6
Mash with RO	5.68	5.44
Mash with Madison Hard	6.12	5.96
Mash with Madison Soft	6.26	6.13

HOW DO WE LOWER OUR MASH PH

- ACID REST – 2-3 HRS @ 94 F = CONVERTS PHYTIN WITH PHYTASE
- SOUR MASH – 24 HRS @ RT = LACTIC ACID BACTERIA PRODUCES LACTIC ACID
- USE SPECIALTY MALTS - DARK MALTS/ACIDULATED MALT = HIGH PHOSPHATE/LACTIC ACID
- DILUTE WITH RO = DECREASE ALKALINITY
- PRE-BOIL = PRECIPITATE OUT BICARBONATE (REDUCES 364 PPM BICARBONATE TO 164 PPM)
- SLAKED LIME = PRECIPITATE OUT BICARBONATE
- ADDING MINERALS = INTRODUCE MORE CALCIUM TO COMBINE WITH BICARBONATE
- ADDING ACIDS = PHOSPHORIC, LACTIC, MALIC, CITRIC, OR TARTARIC
- FIVE STAR “5.2” = LIKELY PHOSPHATE BLEND TO HIT MASH PH – NOT FORMULATED FOR HIGH BICARBONATE LEVELS

HOW MUCH DO WE ADD?

- READ MARK G'S BREWING WITH WATER (NOT SUCH A DUMB NAME NOW, RIGHT BRIAN?)
- BRU'N WATER*
- BEERSMITH WATER
- PRO-MASH
- OTHER WEBSITES (https://www.brewersfriend.com/water-chemistry/)

BRU'N WATER – DEMO – WATER PROFILE

Bru'n Water

Link to Bru'n Water website for updates and to donate

Enter data into Light Blue cells, Yellow cells display calculated results, Pink cells contain selection boxes

Program Volume Setting	Gallons	< Select

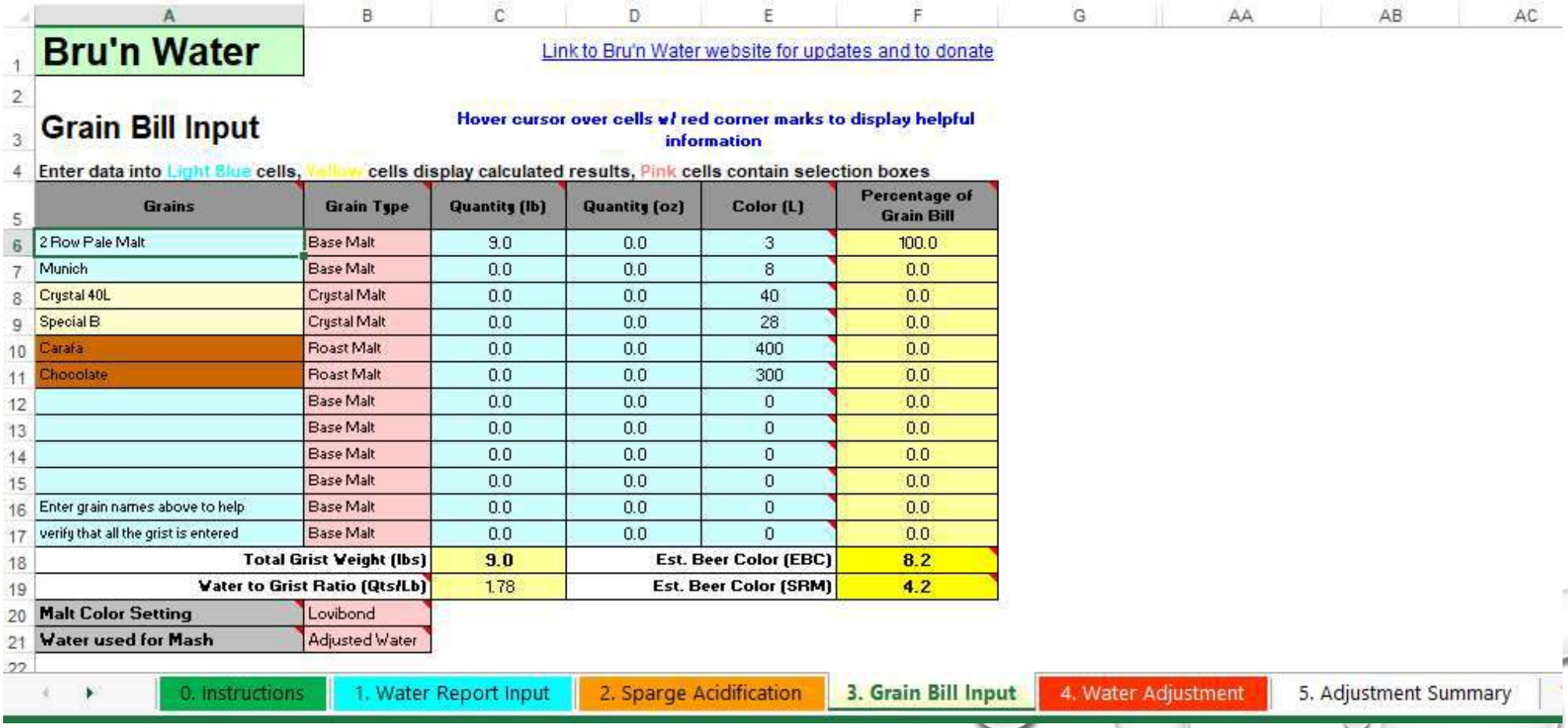
Water Report Input

Hover cursor over cells w/ red corner marks to display informa

Cations	Enter Ion Concentrations from Water Report (mg/L or ppm)		Anions	
Calcium (Ca)	70.0	364.0	Bicarbonate (HCO_3)	
Magnesium (Mg)	41.0	0.0	Carbonate (CO_3)	
Sodium (Na)	9.0	21.0	Sulfate (SO_4)	multiply lab result by 3 if lab reports as SO_4-S
		19.0	Chloride (Cl)	
Optional Inputs (not required, but may improve ion balance)		0.0	Nitrate (NO_3)	multiply lab result by 4.43 if lab reports as NO_3-N
Potassium (K)	0.0	0.0	Nitrite (NO_2)	
Iron (Fe)	0.0	0.0	Fluoride (F)	

Calculated Alkalinity		
Alkalinity (ppm as $CaCO_3$)	298	<-- This value is automatically entered on the **Sparge Acidification** sheet

BRU'N WATER – DEMO - GRAINS



Bru'n Water

Link to Bru'n Water website for updates and to donate

Grain Bill Input

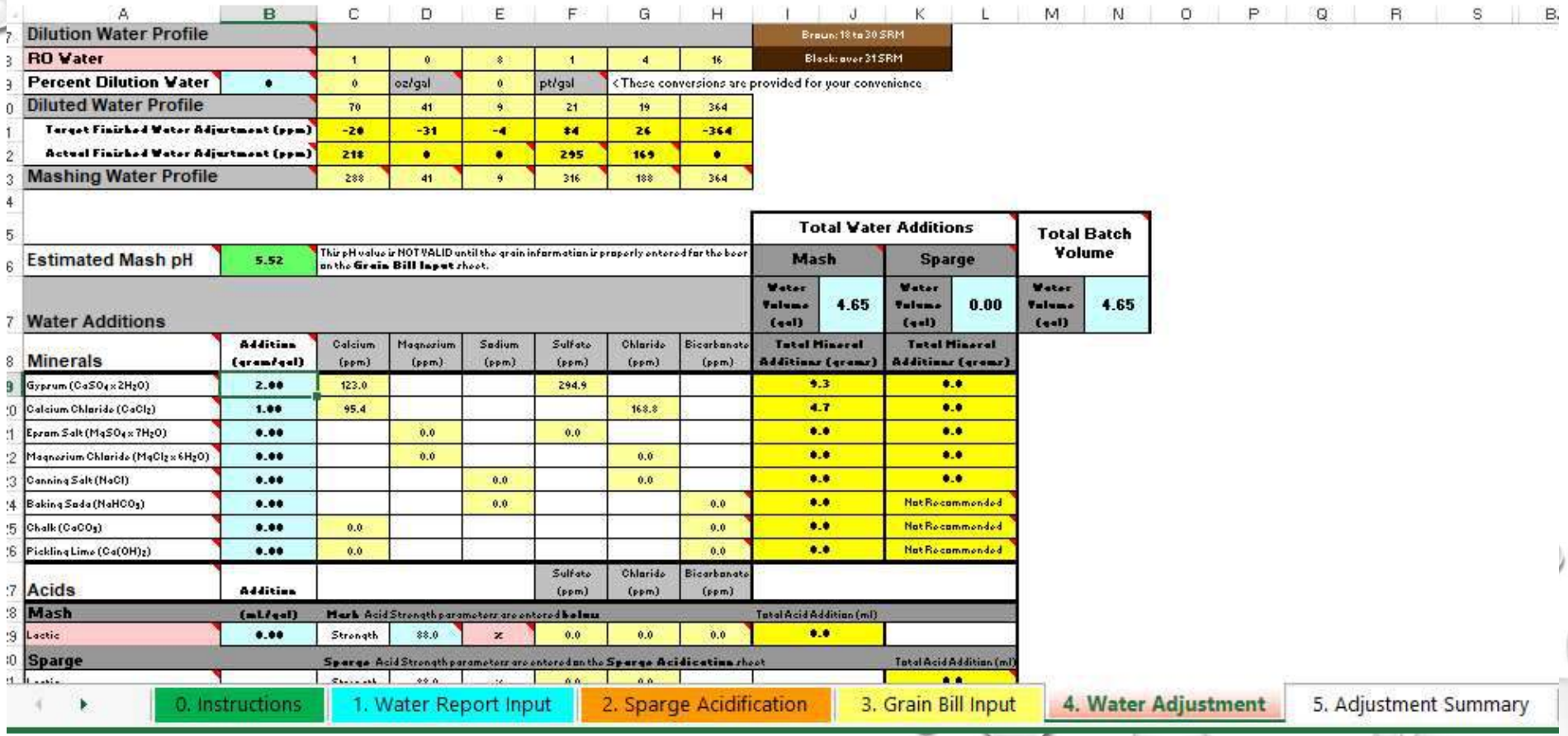
Hover cursor over cells w/ red corner marks to display helpful information

Enter data into Light Blue cells, Yellow cells display calculated results, Pink cells contain selection boxes

Grains	Grain Type	Quantity (lb)	Quantity (oz)	Color (L)	Percentage of Grain Bill
2 Row Pale Malt	Base Malt	9.0	0.0	3	100.0
Munich	Base Malt	0.0	0.0	8	0.0
Crystal 40L	Crystal Malt	0.0	0.0	40	0.0
Special B	Crystal Malt	0.0	0.0	28	0.0
Carafa	Roast Malt	0.0	0.0	400	0.0
Chocolate	Roast Malt	0.0	0.0	300	0.0
	Base Malt	0.0	0.0	0	0.0
	Base Malt	0.0	0.0	0	0.0
	Base Malt	0.0	0.0	0	0.0
	Base Malt	0.0	0.0	0	0.0
Enter grain names above to help	Base Malt	0.0	0.0	0	0.0
verify that all the grist is entered	Base Malt	0.0	0.0	0	0.0
Total Grist Weight (lbs)		**9.0**	**Est. Beer Color (EBC)**		**8.2**
Water to Grist Ratio (Qts/Lb)		1.78	**Est. Beer Color (SRM)**		**4.2**
Malt Color Setting	Lovibond				
Water used for Mash	Adjusted Water				

0. Instructions | 1. Water Report Input | 2. Sparge Acidification | 3. Grain Bill Input | 4. Water Adjustment | 5. Adjustment Summary

BRU'N WATER – DEMO – MINERAL ADDITIONS



Dilution Water Profile								Braun: 18 to 30 SRM	
RO Water		1	0	8	1	4	16	Black: over 31 SRM	
Percent Dilution Water	0	0	oz/gal	0	pt/gal	<These conversions are provided for your convenience			
Diluted Water Profile		70	41	9	21	19	364		
Target Finished Water Adjustment (ppm)		-20	-31	-4	84	26	-364		
Actual Finished Water Adjustment (ppm)		218	0	0	295	169	0		
Mashing Water Profile		288	41	9	316	188	364		

Estimated Mash pH	5.52	This pH value is NOT VALID until the grain information is properly entered for the beer on the **Grain Bill Input** sheet.

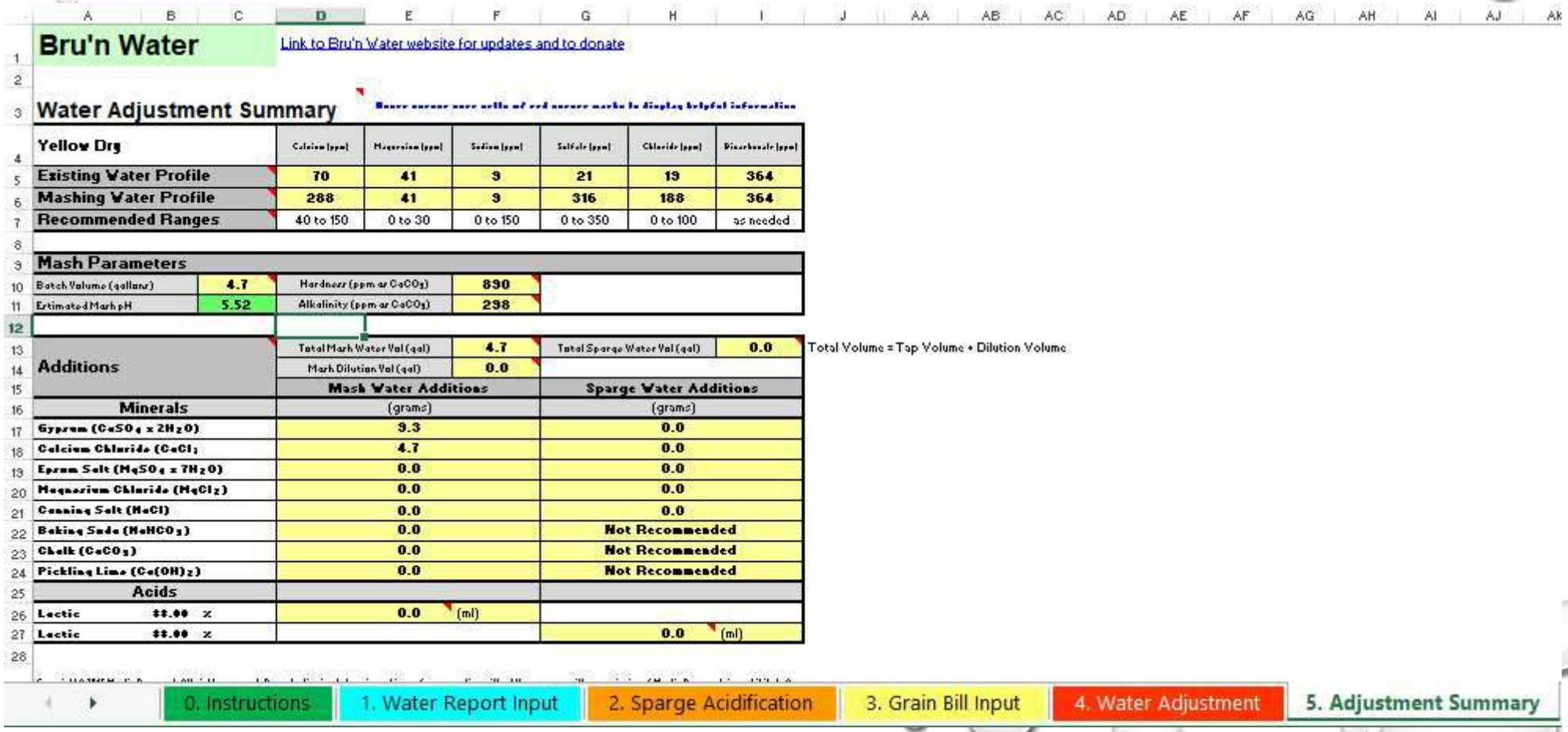
Total Water Additions				Total Batch Volume	
Mash		Sparge			
Water Volume (gal)	4.65	Water Volume (gal)	0.00	Water Volume (gal)	4.65

Water Additions									
Minerals	Addition (gram/gal)	Calcium (ppm)	Magnesium (ppm)	Sodium (ppm)	Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)	Total Mineral Additions (grams)	Total Mineral Additions (grams)
Gypsum ($CaSO_4 \times 2H_2O$)	2.00	123.0			294.9			9.3	0.0
Calcium Chloride ($CaCl_2$)	1.00	95.4				168.8		4.7	0.0
Epsom Salt ($MgSO_4 \times 7H_2O$)	0.00		0.0		0.0			0.0	0.0
Magnesium Chloride ($MgCl_2 \times 6H_2O$)	0.00		0.0			0.0		0.0	0.0
Canning Salt (NaCl)	0.00			0.0		0.0		0.0	0.0
Baking Soda ($NaHCO_3$)	0.00			0.0			0.0	0.0	Not Recommended
Chalk ($CaCO_3$)	0.00	0.0					0.0	0.0	Not Recommended
Pickling Lime ($Ca(OH)_2$)	0.00	0.0					0.0	0.0	Not Recommended

Acids	Addition			Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)		
Mash	(ml/gal)	**Mash** Acid Strength parameters are entered **below**					Total Acid Addition (ml)	
Lactic	0.00	Strength	88.0	%	0.0	0.0	0.0	0.0	
Sparge		**Sparge** Acid Strength parameters are entered on the **Sparge Acidification** sheet						Total Acid Addition (ml)
Lactic		Strength	88.0	%	0.0	0.0		0.0

0. Instructions | 1. Water Report Input | 2. Sparge Acidification | 3. Grain Bill Input | 4. Water Adjustment | 5. Adjustment Summary

BRU'N WATER – DEMO – FORMULA



Bru'n Water — Link to Bru'n Water website for updates and to donate

Water Adjustment Summary

Yellow Drg	Calcium (ppm)	Magnesium (ppm)	Sodium (ppm)	Sulfate (ppm)	Chloride (ppm)	Bicarbonate (ppm)
Existing Water Profile	70	41	9	21	19	364
Mashing Water Profile	288	41	9	316	188	364
Recommended Ranges	40 to 150	0 to 30	0 to 150	0 to 350	0 to 100	as needed

Mash Parameters

Batch Volume (gallons)	4.7	Hardness (ppm as $CaCO_3$)	890
Estimated Mash pH	5.52	Alkalinity (ppm as $CaCO_3$)	298

Additions

	Total Mash Water Vol (gal)	4.7	Total Sparge Water Vol (gal)	0.0
	Mash Dilution Vol (gal)	0.0		

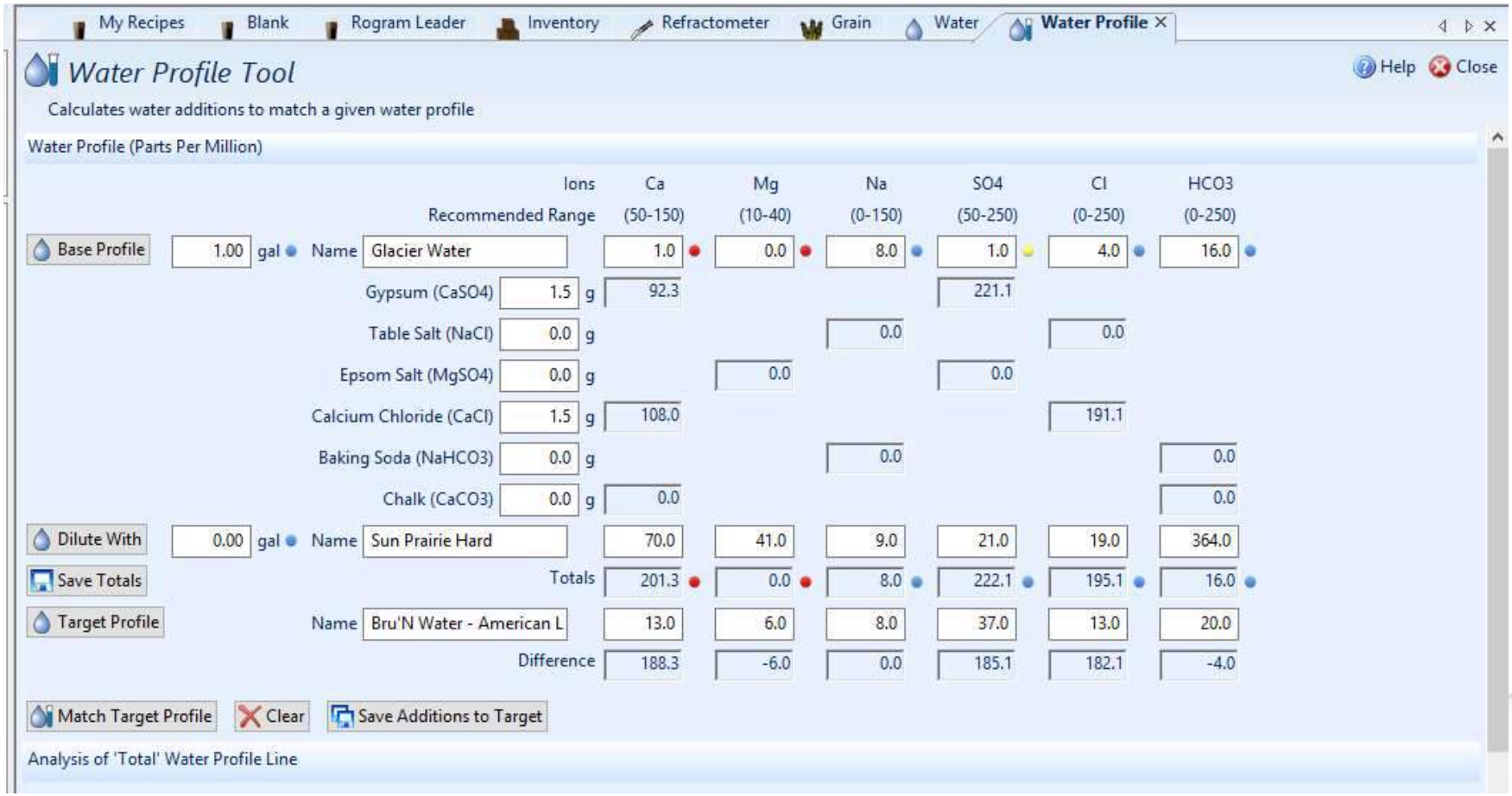
Total Volume = Tap Volume + Dilution Volume

Minerals	Mash Water Additions (grams)	Sparge Water Additions (grams)
Gypsum ($CaSO_4 \times 2H_2O$)	9.3	0.0
Calcium Chloride ($CaCl_2$)	4.7	0.0
Epsom Salt ($MgSO_4 \times 7H_2O$)	0.0	0.0
Magnesium Chloride ($MgCl_2$)	0.0	0.0
Canning Salt ($NaCl$)	0.0	0.0
Baking Soda ($NaHCO_3$)	0.0	Not Recommended
Chalk ($CaCO_3$)	0.0	Not Recommended
Pickling Lime ($Ca(OH)_2$)	0.0	Not Recommended
Acids		
Lactic 88.00 %	0.0 (ml)	
Lactic 88.00 %		0.0 (ml)

0. Instructions | 1. Water Report Input | 2. Sparge Acidification | 3. Grain Bill Input | 4. Water Adjustment | 5. Adjustment Summary

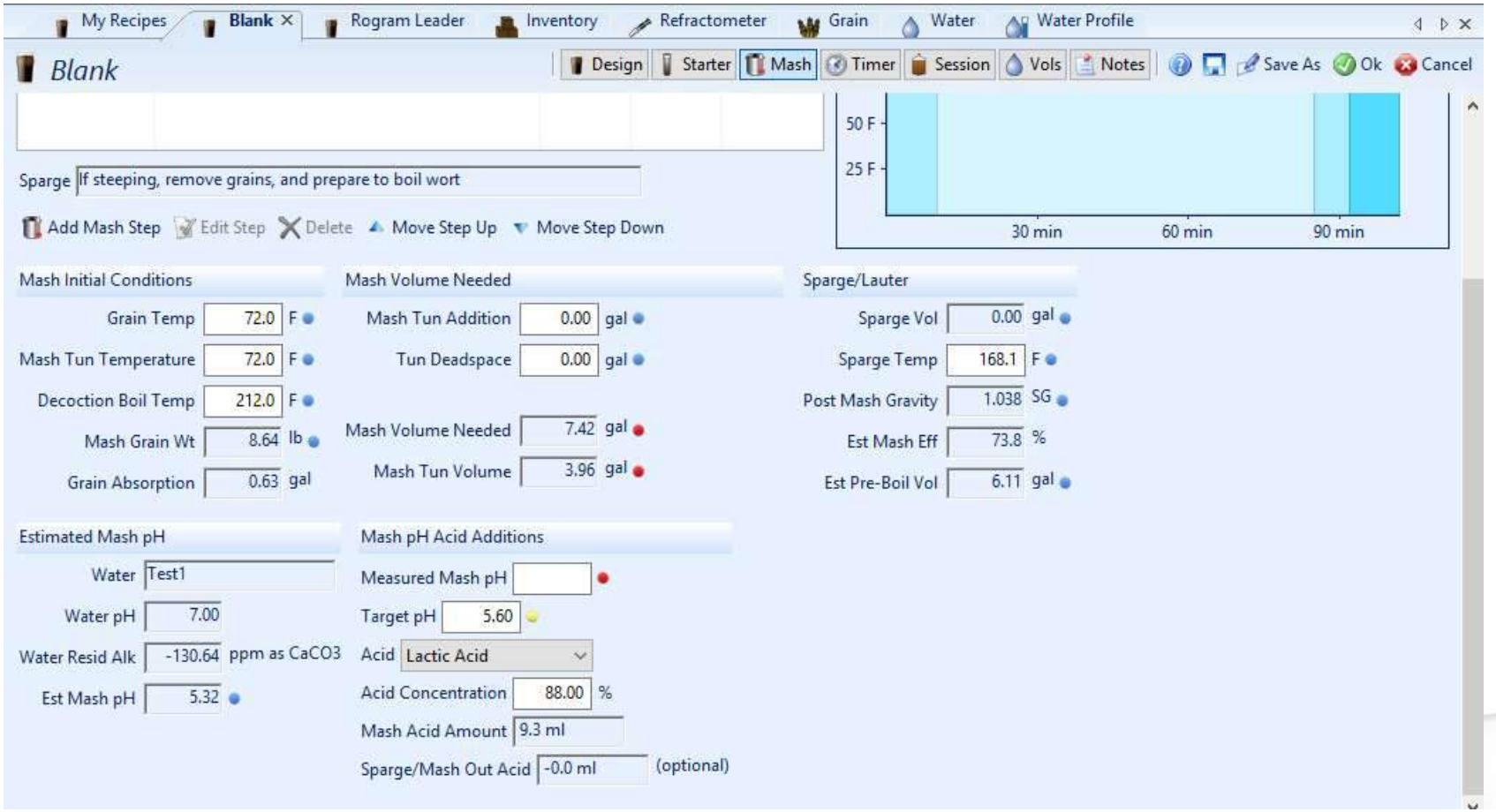
BEERSMITH 2– WATER PROFILE NOTE

YOU MUST SET YOUR MINERAL ADDS IN THE WATER PROFILE TOOL TO GET PROPER MASH PH



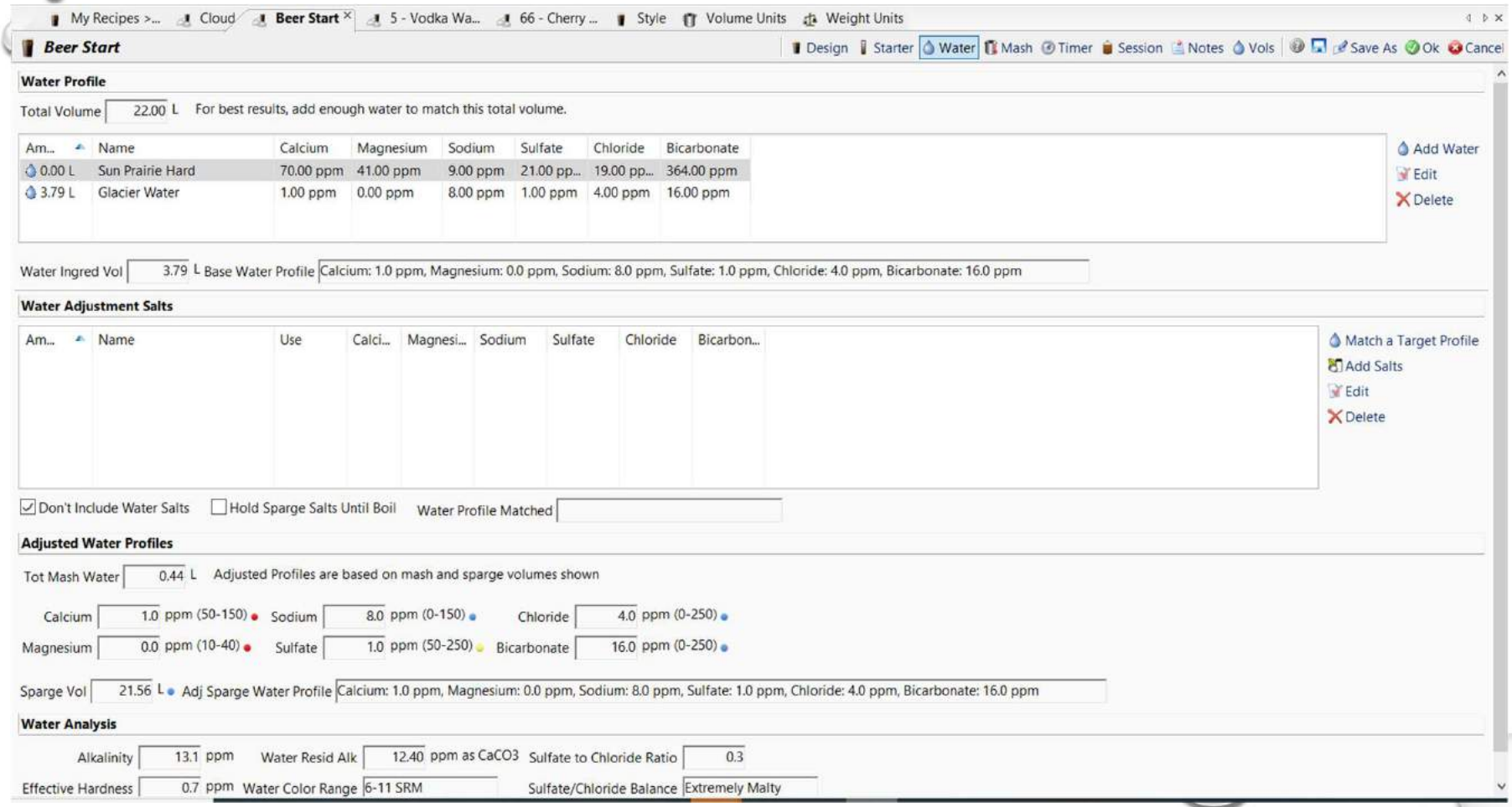
BEERSMITH 2– MASH TAB

IN ADDITION TO EST MASH PH, WILL CALCULATE AMOUNT OF ACID TO ADD BASED ON MEASURED PH – TRY ADDING ½ BEFORE MASH



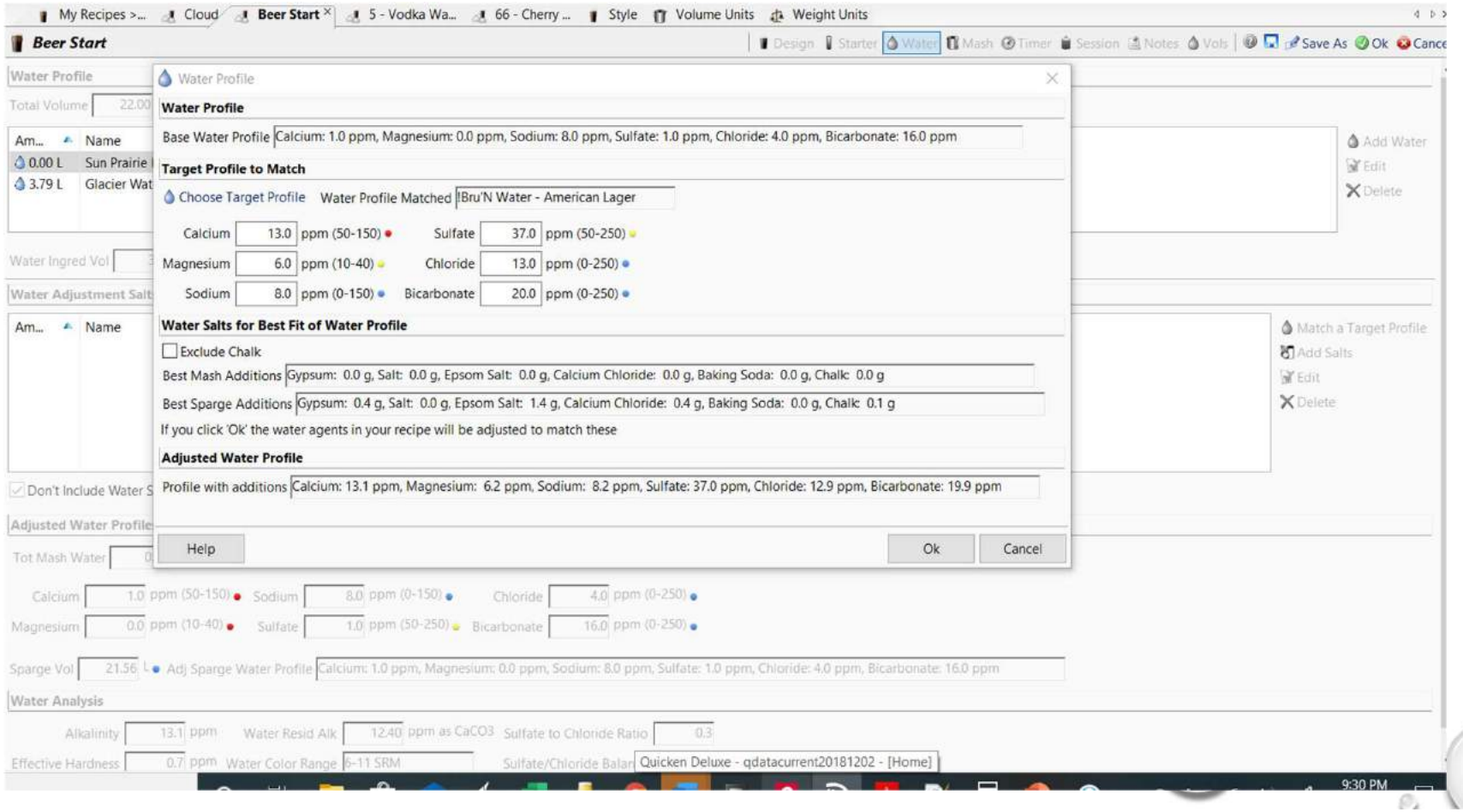
BEERSMITH 3– WATER PROFILE NOTE

SET YOUR MINERAL PROFILE FIRST



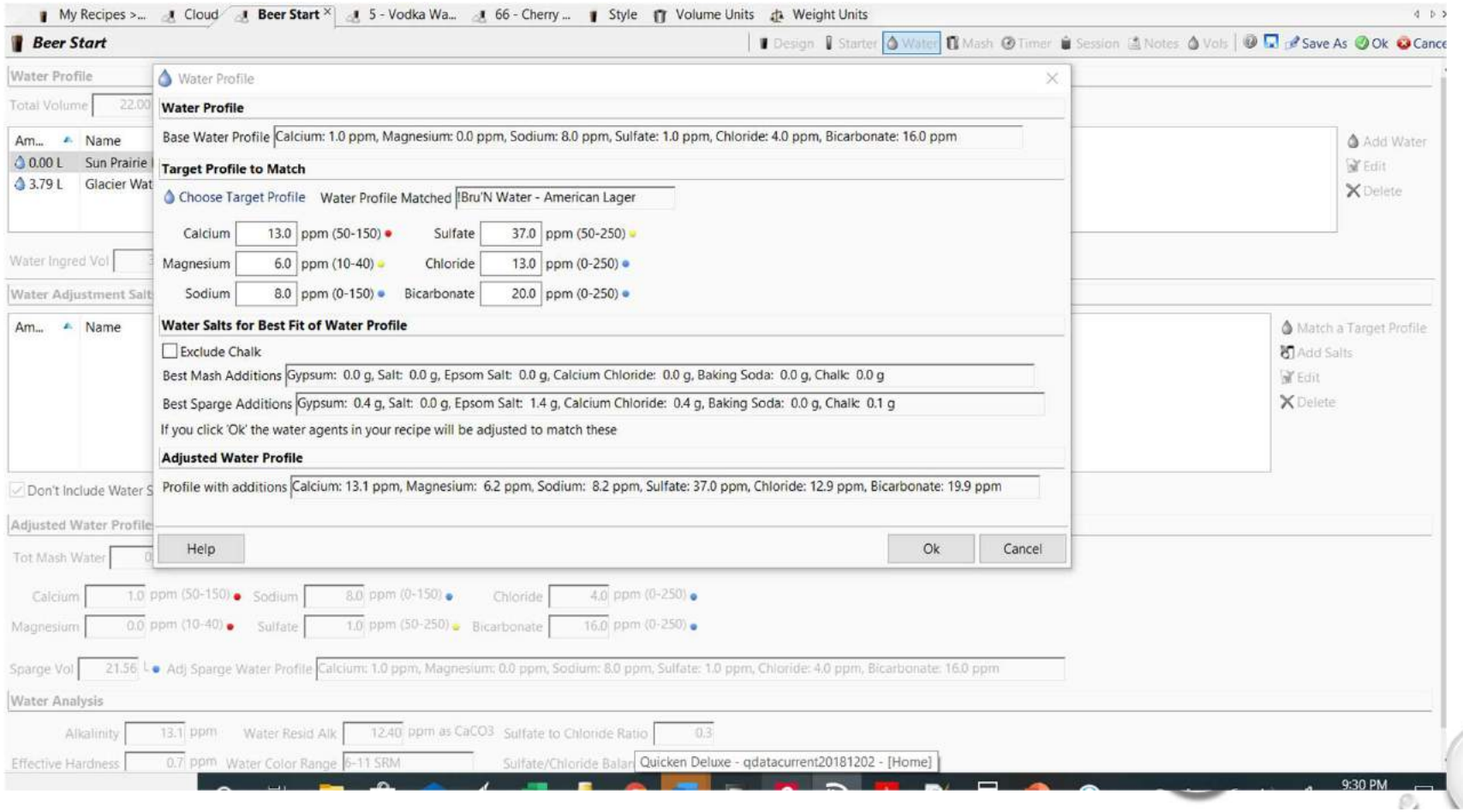
BEERSMITH 3– WATER PROFILE NOTE

DETERMINE YOUR FINAL PROFILE



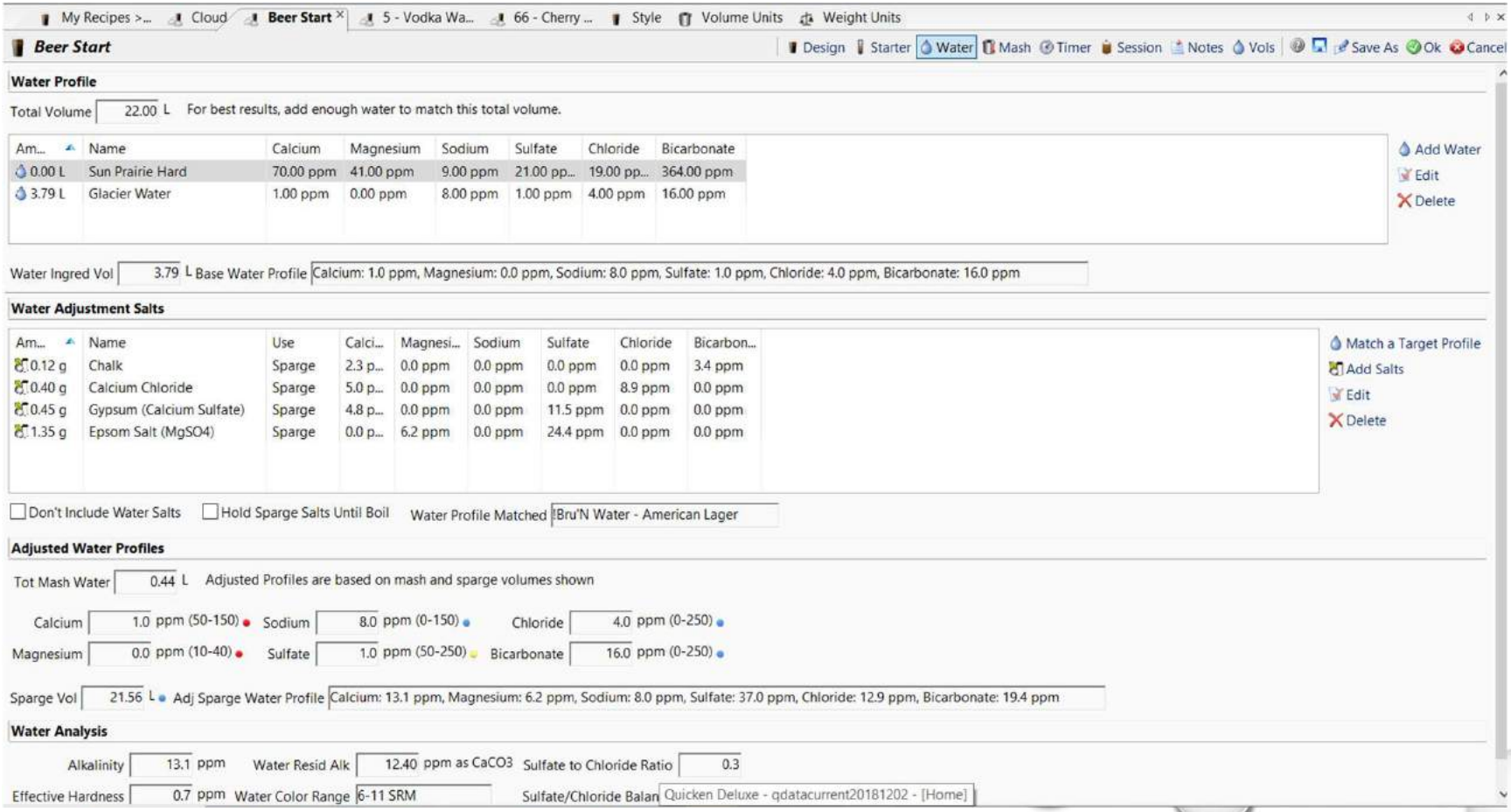
BEERSMITH 3– WATER PROFILE NOTE

DETERMINE YOUR FINAL PROFILE



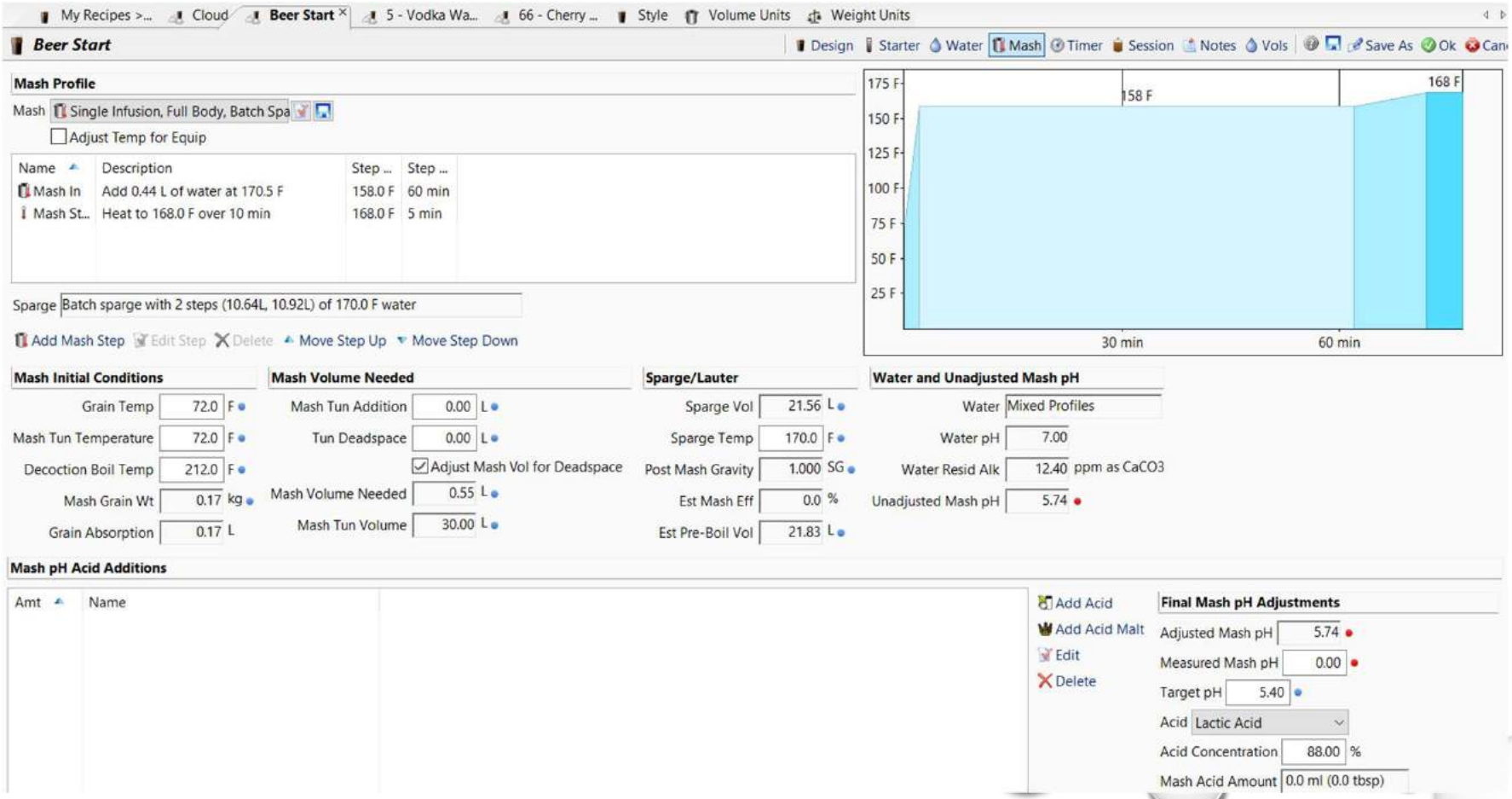
BEERSMITH 3– WATER PROFILE NOTE

BEERSMITH WILL CALCULATE YOUR INGREDIENT ADDS



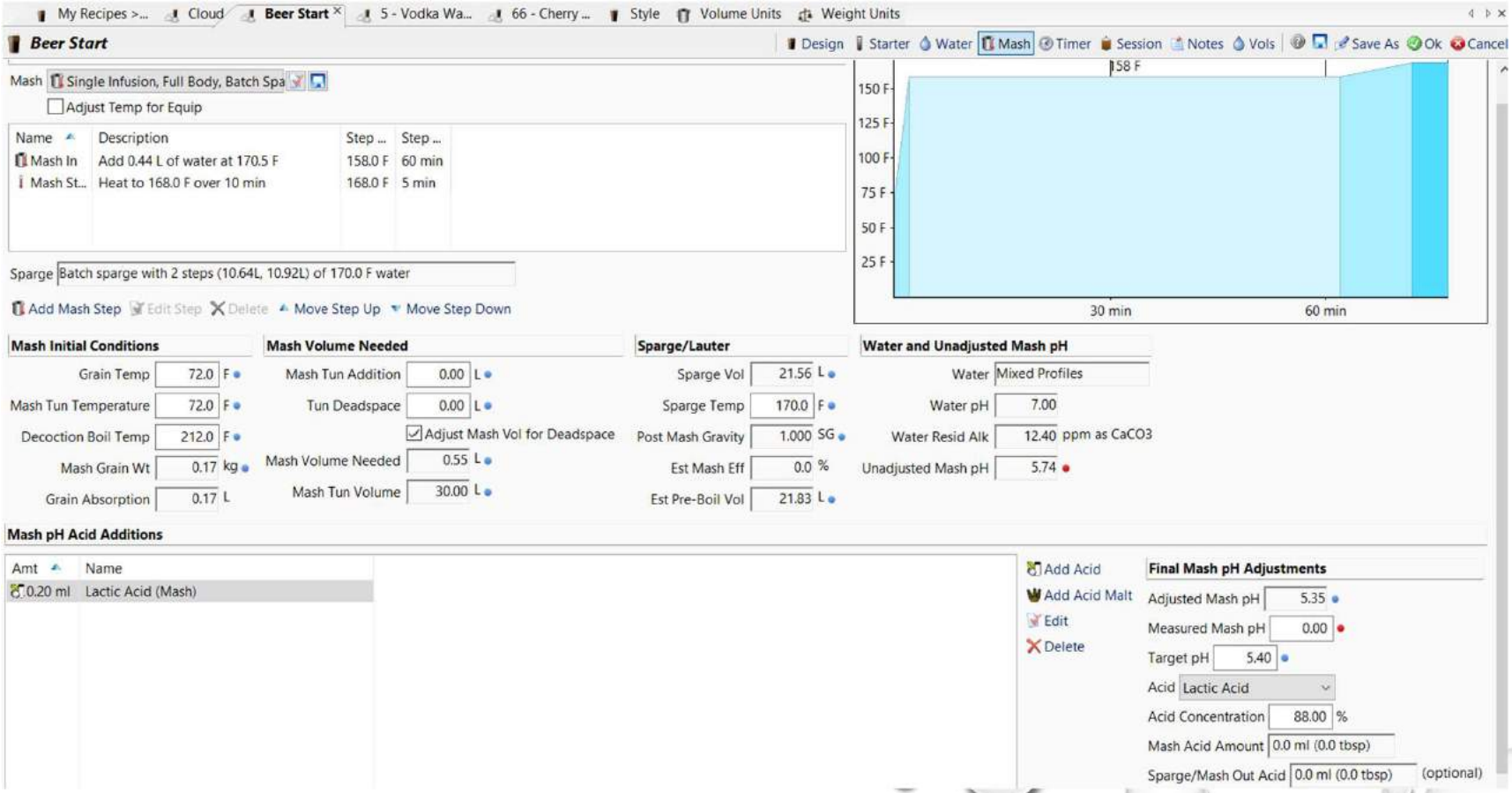
BEERSMITH 3– WATER PROFILE NOTE

MASH TAB WILL GIVE YOU ESTIMATED PH



BEERSMITH 3– WATER PROFILE NOTE

CAN CALCULATE AMOUNT TO INCLUDE IN MASH TO HIT DESIRED PH



RECIPES – WITH MINERAL ADDITION

IPA	Stout
8 lbs Pale Malt (2 Row)	4 lbs 12.53 oz Pale Malt (Maris Otter)
10.31 oz Crystal 40 L	8.50 oz Biscuit Malt
7.3 g gypsum	8.50 oz Chocolate Malt
7.3 g Calcium Chloride	8.50 oz Roasted Barley
4.82 gallons RO	4.65 gallons RO
Mash pH 5.32	Mash pH 5.44

PART II: PUTTING IT ALL TOGETHER

- FORMULATION
  - WATER – MASH VS. SPARGE
  - MINERALS
    - MASH PH
    - FLAVOR IMPACT IN FINAL BEER
- PREPARATION/BREW DAY

GEAR

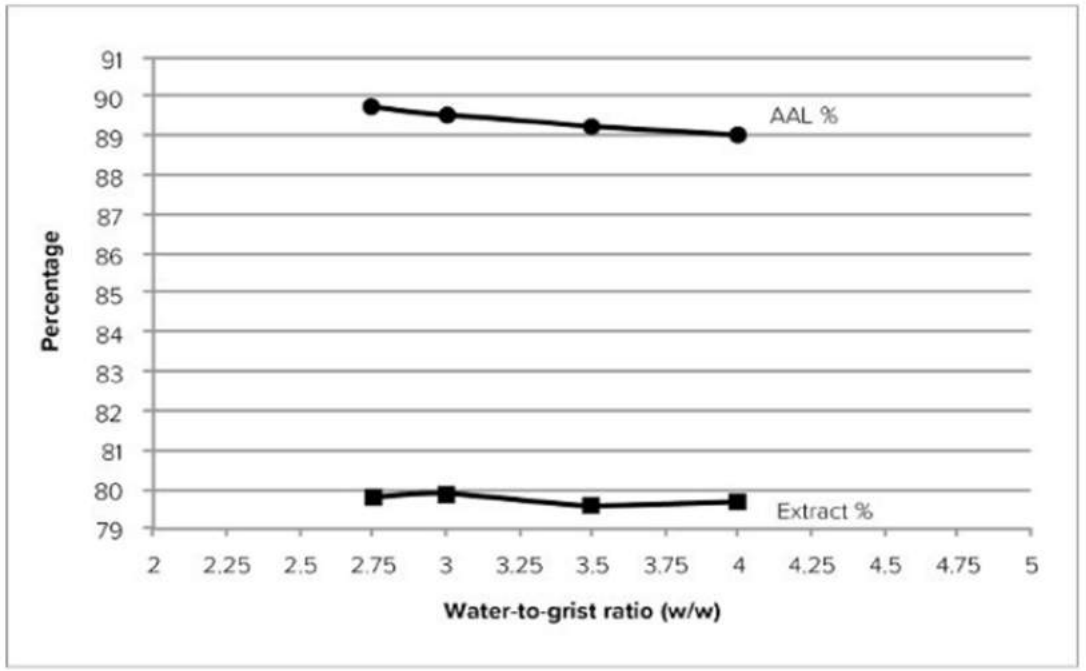
Dr.meter 0.01 Resolution High Accuracy Pocket Size pH Meter with ATC	$37
AWS Series Digital Pocket Weight Scale	$15
88% Lactic Acid	$ 7
BAXA ExactaMed Oral Liquid Medication Syringe	$ 6
Sodium Hydroxide 4 oz.	$ 8
TDS Meter	$14
Frienda 4 Pack Large Plastic Syringe for Scientific Labs	$ 8

WATER ADDITIONS

- TOTAL WATER
  - CALCULATE BACKWARDS FROM BATCH VOLUME+PROCESS LOSSES+ABSORPTION
- WATER IN MASH
  - LOW WTG - LESS FERMENTABLE, SWEETER MASH
  - HIGH WTG – DILUTES ENZYMES, LONGER MASH
- SWEET SPOT

  1.25 – 2.00 QT/LB
- SPARGE WATER

  SPARGE WATER = TOTAL WATER-MASH WATER



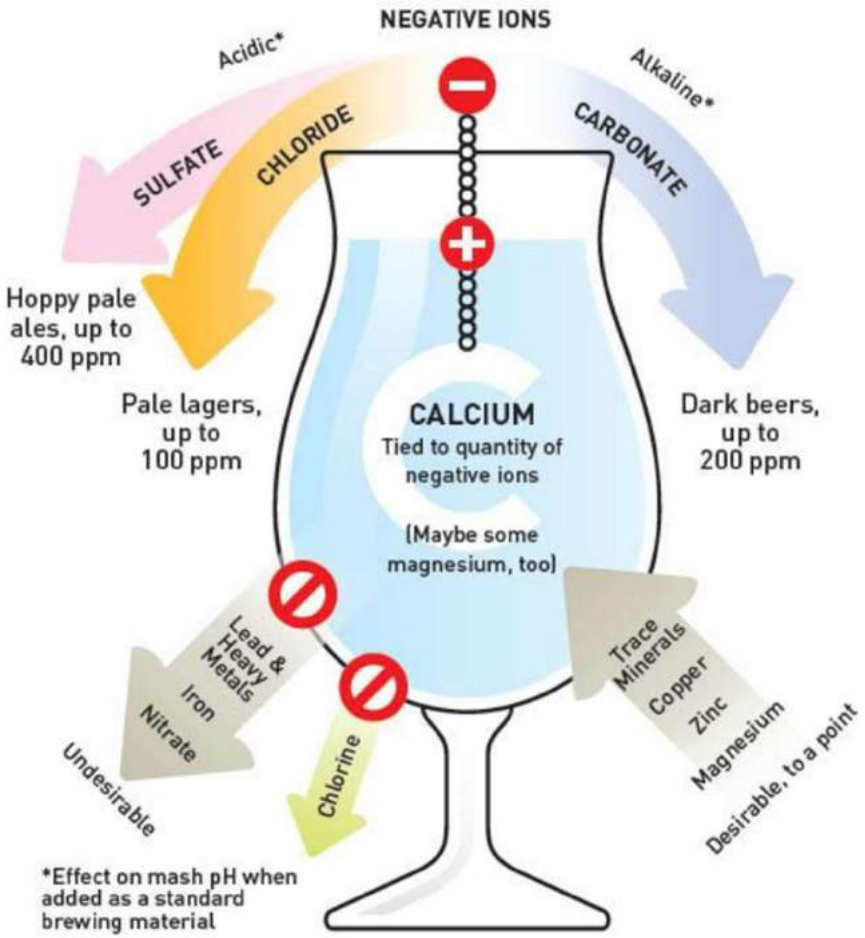
MINERAL PROFILE

- CHOOSE MASH PROFILE
  - MATCH LOCALITIES
    - DOESN'T ACCOUNT FOR BREWERIES WATER TREATMENT
  - USE STYLE RECOMMENDATIONS
  - TARGET MINERAL CONCENTRATIONS
    - CALCIUM (50-200 PPM)

    – ENHANCES ENZYME ACTIVITY IN MASH, HELPS PROTEIN COAGULATION/TRUB FORMATION, ASSISTS WITH YEAST METABOLISM AND FLOCCULATION

    - SODIUM

MINERAL PROFILE



TARGET MINERAL CONCENTRATIONS

- CALCIUM (50-200 PPM)

– ENHANCES ENZYME ACTIVITY IN MASH, HELPS PROTEIN COAGULATION/TRUB FORMATION, ASSISTS WITH YEAST METABOLISM AND FLOCCULATION

- MAGNESIUM (5-40 PPM)
- SODIUM (<100 PPM)

– SWEETENS MALT CHARACTER, IMPROVES MOUTHFEEL AND FULLNESS IN PALE BEERS

- CHLORIDE (50-200 PPM)

– ENHANCES ROUNDNESS, SWEETNESS, AND FULLNESS OF MALTS, CAN CORRODE METAL

- SULFATE (50-500 PPM)

– ENHANCES ASSERTIVENESS AND DRYNESS OF HOPS

- SULFATE-CHLORIDE RATIO (0.5-9)

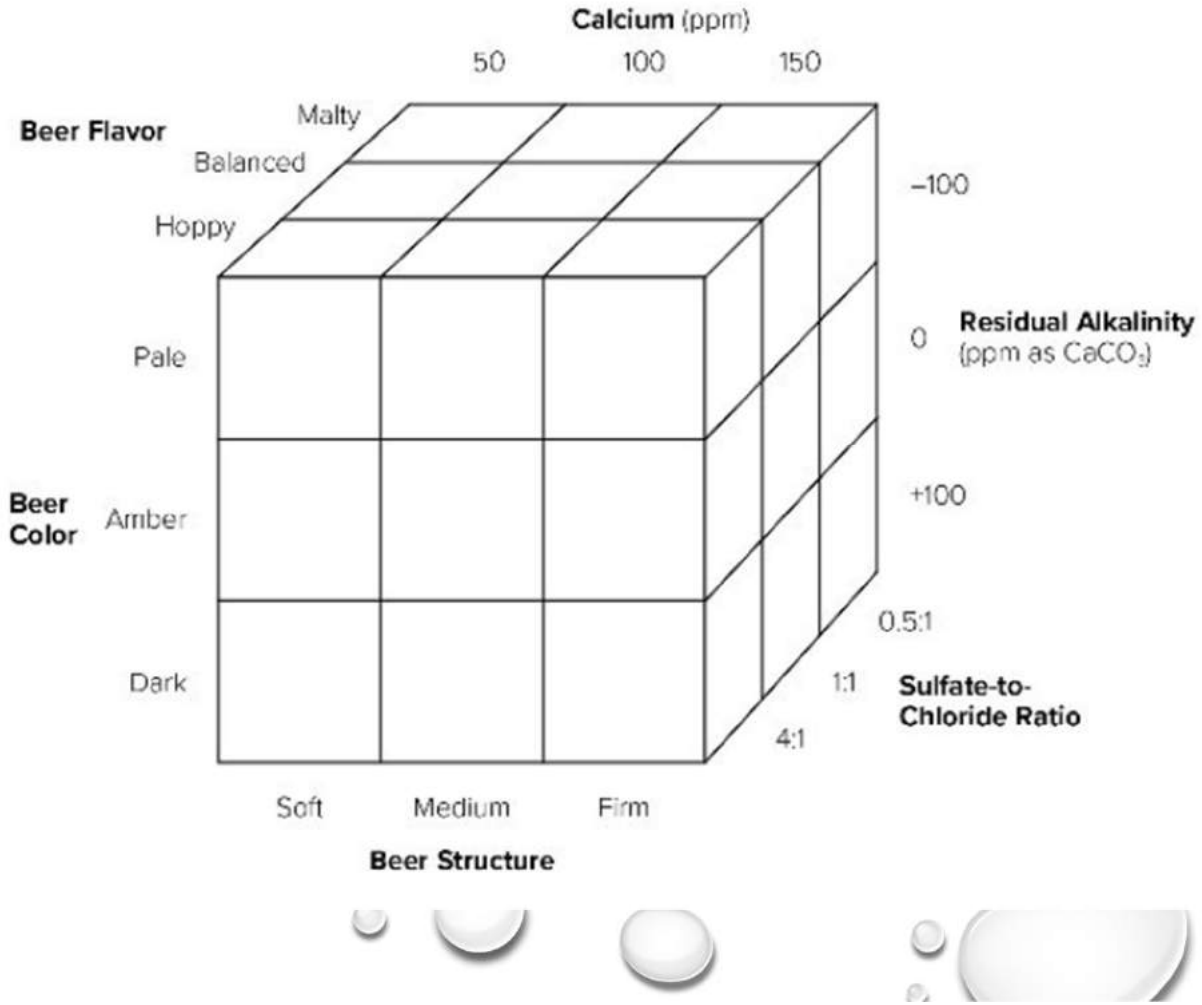
– LOW RATIO IS MALTY, HIGH RATIO IS HOPPY

MASHING IN WATER

- CHECK PH
- TEMPERATURE CORRECT PH
  - ATC WILL CORRECT INSTRUMENTS TEMPERATURE DEPENDENT RESPONSE
  - DOES NOT ACCOUNT FOR PH SHIFT IN SOLUTION
  - PH= PH _mash+0.0055*(T-T_room) (C)
  - PH= PH _mash+0.00306*(T-T_room) (F)
- CORRECT PH AS NEEDED
  - LACTIC ACID
  - PHOSPHORIC ACID
  - CHALK/SODIUM BICARBONATE
  - SLAKED LIME/SODIUM HYDROXIDE
  - GYPSUM/CALCIUM CHLORIDE

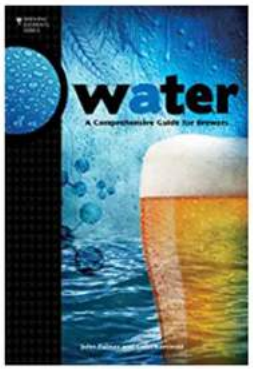
MINERAL ADDITION

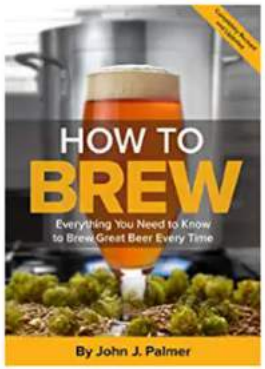
- SLOW AND STEADY
  - CAN ALWAYS ADD MORE
  - BUT CAN'T TAKE OUT



References

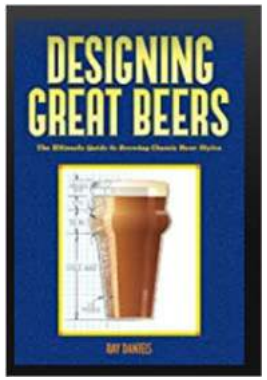
- BRU'N WATER (https://www.brunwater.com/)
- BRAUKAISER (http://braukaiser.com/blog/?s=water&submit=Search)
- EXPERIMENTAL HOMEBREWING (https://www.experimentalbrew.com/podcast/brew-files-episode-86-water-primer)
- BEERSMITH (http://beersmith.com/)
- JOHN PALMER





RANDY MOSHER

RAY DANIELS



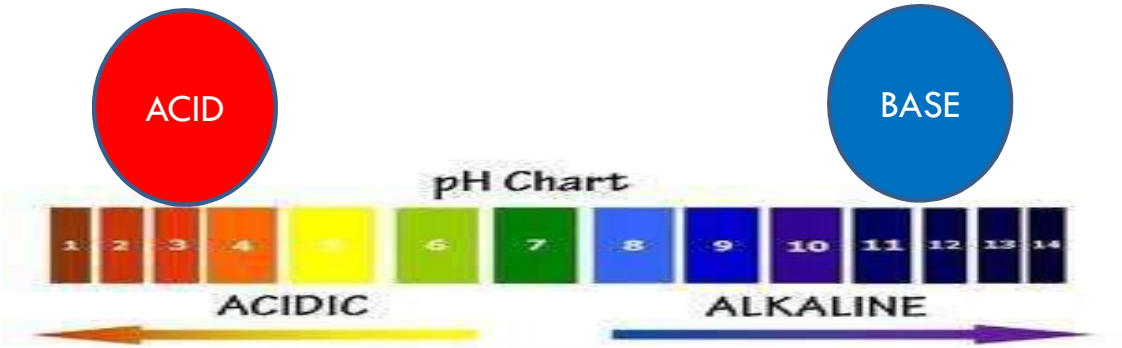

PART III: EXPERIMENTAL
I.E. HERE THERE BE DRAGONS
-MEADS
-CIDERS
-WINES
-SOURS

MEADS, CIDERS, WINES, AND SOURS

- FERMENTATIONS OCCUR AT LOWER PH
- NUTRIENT NEEDS COULD BE LOW
- A LOT OF CHARACTERISTIC FLAVORS DERIVED FROM WEAK ACIDS (MALIC, CITRIC, TARTARIC, LACTIC)
- USE IN PREPARATION (MEAD, KITS) OR BALANCING

REMINDER FROM PART I

- PH – MEASURE OF HOW ACIDIC (LOW PH) OR ALKALINE (HIGH PH) SOMETHING IS
- TOTAL ACIDITY/ALKALINITY – HOW MUCH RESISTANCE THERE IS TO CHANGE PH



FERMENTATION PH

- IDEAL MUST PH SHOULD BE
  - CIDERS 3.0-3.8
  - MEADS 3.7-4.6
  - WINE 3.4-3.65
- TOO LOW FERMENTATION STALLS
- TOO HIGH – PRONE TO CONTAMINATION/UNDESIRABLE FLAVORS/BLANDNESS/POOR STABILITY

LOCAL WATER PROFILES

	RO	Madison Hard	Madison Soft
Calcium	1	70	3
Magnesium	0	41	2
Sodium	8	9	151
Sulfate	1	21	21
Chloride	4	19	19
Bicarbonate	16	364	364
Alkalinity	13	302	302
Hardness	3	259	12

FERMENTATION NUTRIENTS

- POTASSIUM
  - MEADS >300 PPM
  - LIGHT HONEYS ONLY HAVE ~200 PPM PREDILUTION
- NITROGEN
  - LOW NITROGEN CAUSES SLOW FERMENTATION
  - LONG AGING TIMES (DUE TO NITROGEN HARVESTING FROM DEAD YEAST)

FLAVOR COMPOUNDS

- WEAK ACID CONCENTRATION
  - TA MEASURES
  - RECOMMENDED LEVELS
    - MEADS 0.6-0.65% (6-6.5 G/L TARTARIC ACID)
    - CIDERS 0.5-0.70% (5-7.0 G/L TARTARIC ACID)
    - WINES 0.6-0.90% (6-9.0 G/L TARTARIC ACID)
- TANNINS
  - ASTRINGENCY
  - ???

ADJUSTMENT OF MUST

- POTASSIUM
  - ADD POTASSIUM CARBONATE (RAISES PH)
  - ADD POTASSIUM CHLORIDE
  - ADD POTASSIUM SULFITE – BUT WAIT FOR YEAST ADDITION
  - LIGHT HONEYS ONLY HAVE ~200 PPM PREDILUTION
- NITROGEN
  - DAP
  - FERMAID K/FERMAID O
  - ADDED THROUGHOUT FERMENTATION

ADJUSTMENT OF MUST

- ACIDS
  - TOO LOW
    - CITRIC ACID
    - MALIC ACID
    - TARTARIC ACID
    - ACID BLEND
  - TOO HIGH
    - POTASSIUM CARBONATE
    - POTASSIUM HYDROXIDE
    - CALCIUM CARBONATE
    - MALOLACTIC FERMENTATION
  - TYPICALLY ADJUSTED BEFORE FERMENTATION

QUESTIONS?