OPEN PIT & STOCKPILE ORE CONTROL FOR CYANIDE HEAP LEACHING to PREVENT A SOUR PAD

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Knight Piesold – ARD Conference – Elko, NV.

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ORE CONTROL

- **Cyanide Leachable - Mill & Heap Leach**
- **Refractory**
  - **Mill {Roaster - Autoclave - Flotation} Grade**
  - **Leach {Biooxidation - ATS} Grade**
- **Waste**
  - **General (Non Acid Generating)**
  - **Acid Generating (PAG)**

METALLURGICAL CHARACTERISTICS

- **Cyanide Gold Extraction**
  - **CN Shake Test - AA for [Au] = AUCN**
  - **Fire Assay**
  - **AA/FA - Theoretical CN Gold Extraction**
- **Preg. Rob**
  - **Spike w/Au CN Shake Test**
  - **Determine [Au] Absorbed by Ore**
  - **PRV = (AUCN + 0.1) - AUPR**
- **Fuel Value = 1.3 (OrgC) + SS - Target 2.5**

MINERAL CHARACTERISTICS

- **Sulfides**
  - **Pyrite - FeS_2** **GQ - 10 microns (*u*m) +**
  - **Arsenopyrite - FeAsS** **GQ - 1-2 microns (*u*m)**
- **Carbonates**
  - **Calcite - $CaCO_3$**
  - **Dolomite - $CaMg(CO_3)_2$**
  - **Siderite - $FeCO_3$**
- **Carbonaceous Material**

ANALYTICAL

- **LECO Total Sulfur & Carbon**
- **Sulfur as a Percent**
  - **% Sulfate Sulfur = SRO**
  - **% Sulfide Sulfur - Roast {% SS} = STOT - SRO**
- **Carbon as a Percent**
  - **% Organic Carbon = CAI = OrgC**
  - **% Carbonate Carbon - Leach HCl {% CC}**
  - **% CC = CTOT - CAI**

AGP

- **Acid Generating Potential - AGP**
  - **Equal to - 1.37 * % SS**
- **Sample Equation:**
  - $2\ FeS_2 + 7\ O_2 + 2\ H_2O \rightarrow 2\ FeSO_4 + 4\ H^+ + 2\ SO_4^{2-}$
- **Leads to Acid Rock Drainage**

ANP

- **Acid Neutralization Potential - ANP**
  - **Equal to 3.67 * % CC**
- **Sample Equation:**
  - $CaCO_3 + 2\,H^+ + SO_4^{2-} \rightarrow CaSO_4 + H_2O + CO_2\uparrow$

NCV

- **Net Carbonate Value - NCV**
  - **Equal to ANP + AGP**
  - **NCV = 3.67 * % CC - 1.37 * % SS**

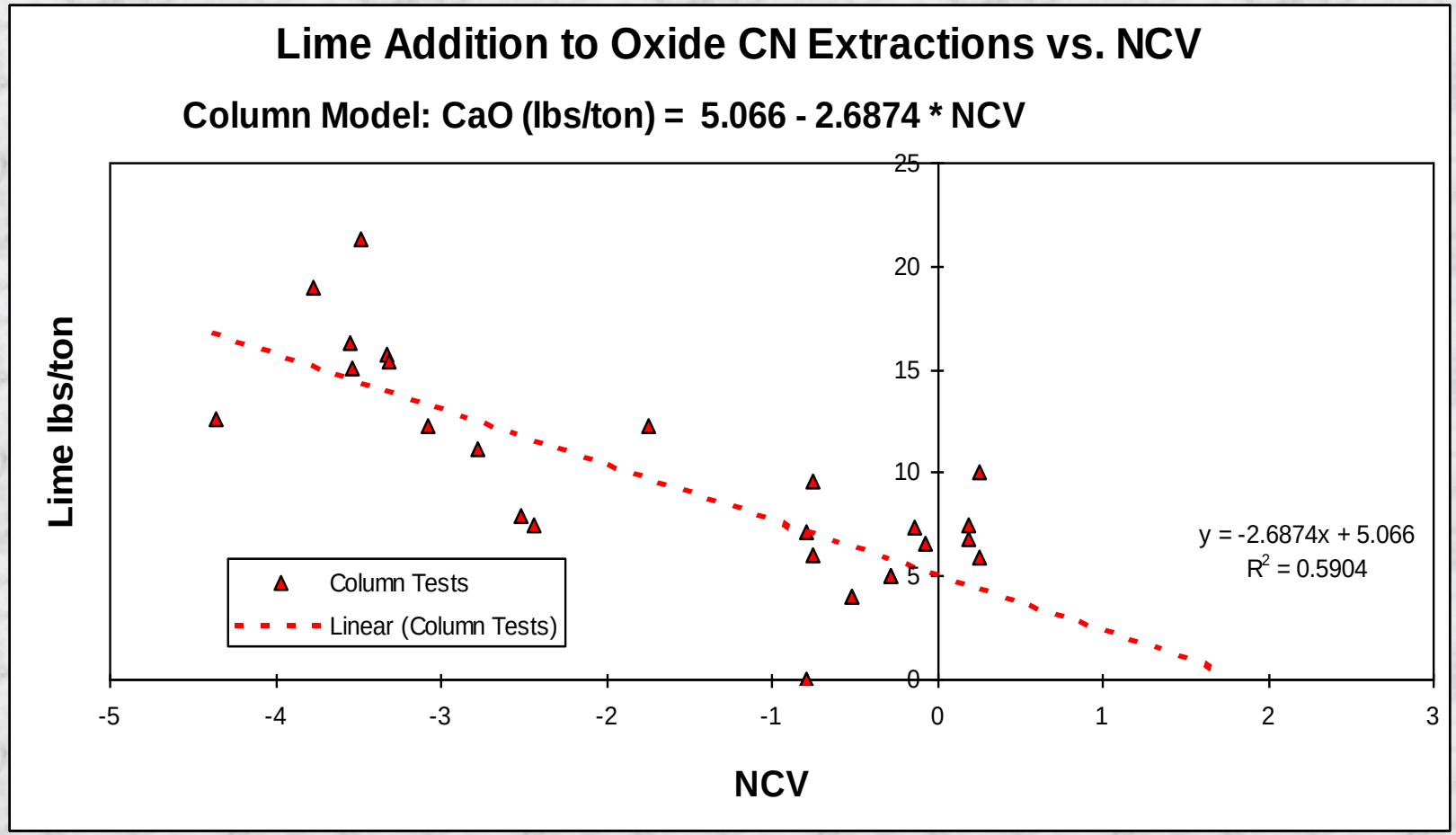
EQUATIONS

- **Cyanide Hydrolyses at pH < 10**
  - $CN^- + H_2O \rightarrow HCN + OH^-$
- **Cyanide Reaction with Sulfides**
  - $2\ FeS + 12\ CN^- + 5\ O_2 + 2\ H_2O \rightarrow 2\ Fe(CN)_6^{4-} + 2\ SO_4^{2-} + 4\ OH^-$
- **Lime Hydrolyses**
  - $CaO + H_2O \rightarrow Ca(OH)_2$

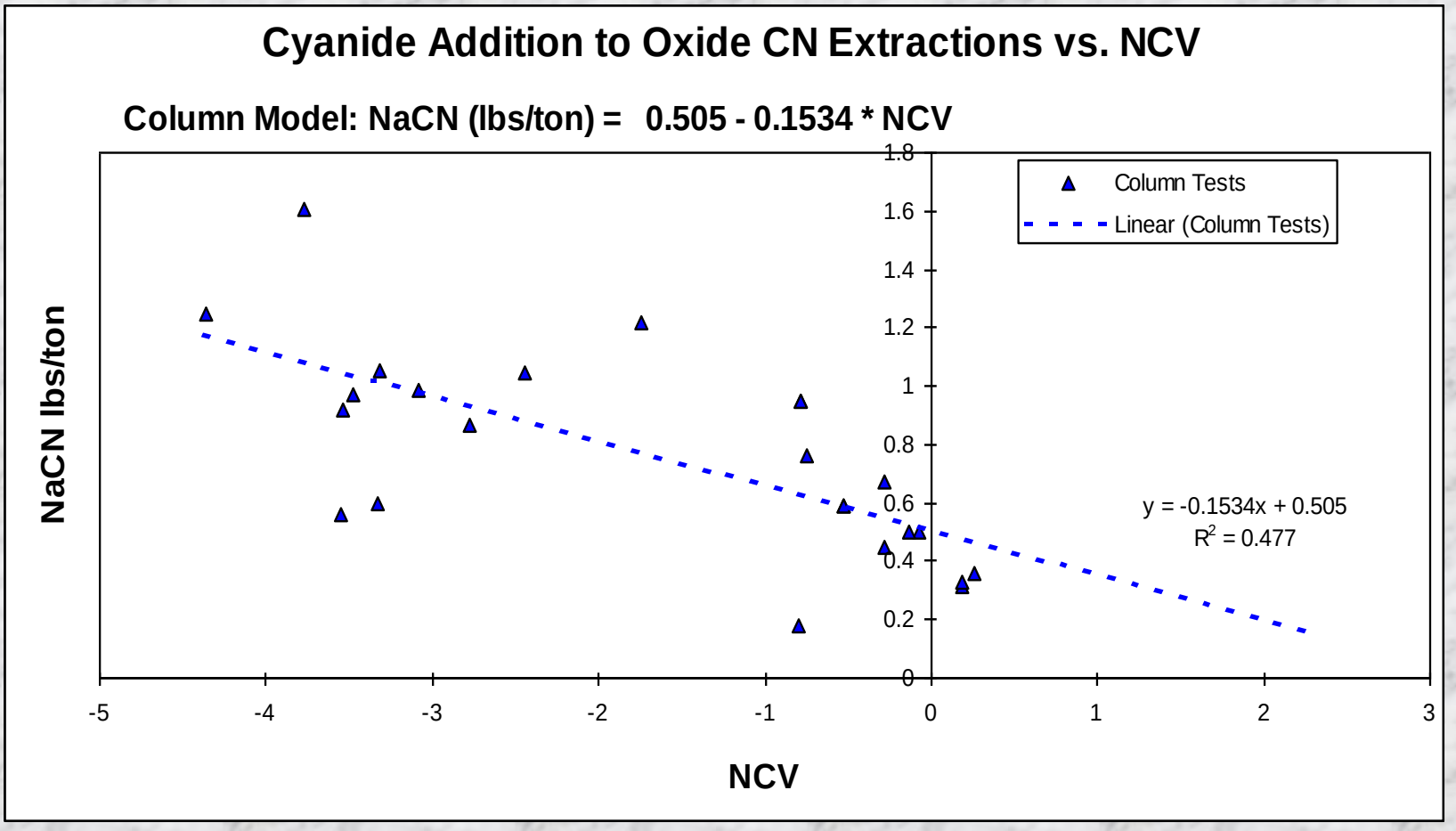
LIME USE MODEL

- **Net Reaction**
  - **$4\ FeS_2 + 8\ CaO + 15\ O_2 + 6\ H_2O$ ➲ $4\ Fe(OH)_3 + 8\ CaSO_4$**
- **Regression Model**
  - **Lime (pounds/ton) = 5.066 - 2.6874 * NCV**
  - **Multiply by Safety Factor: Using S.F. = 2 for NA Stockpiles**

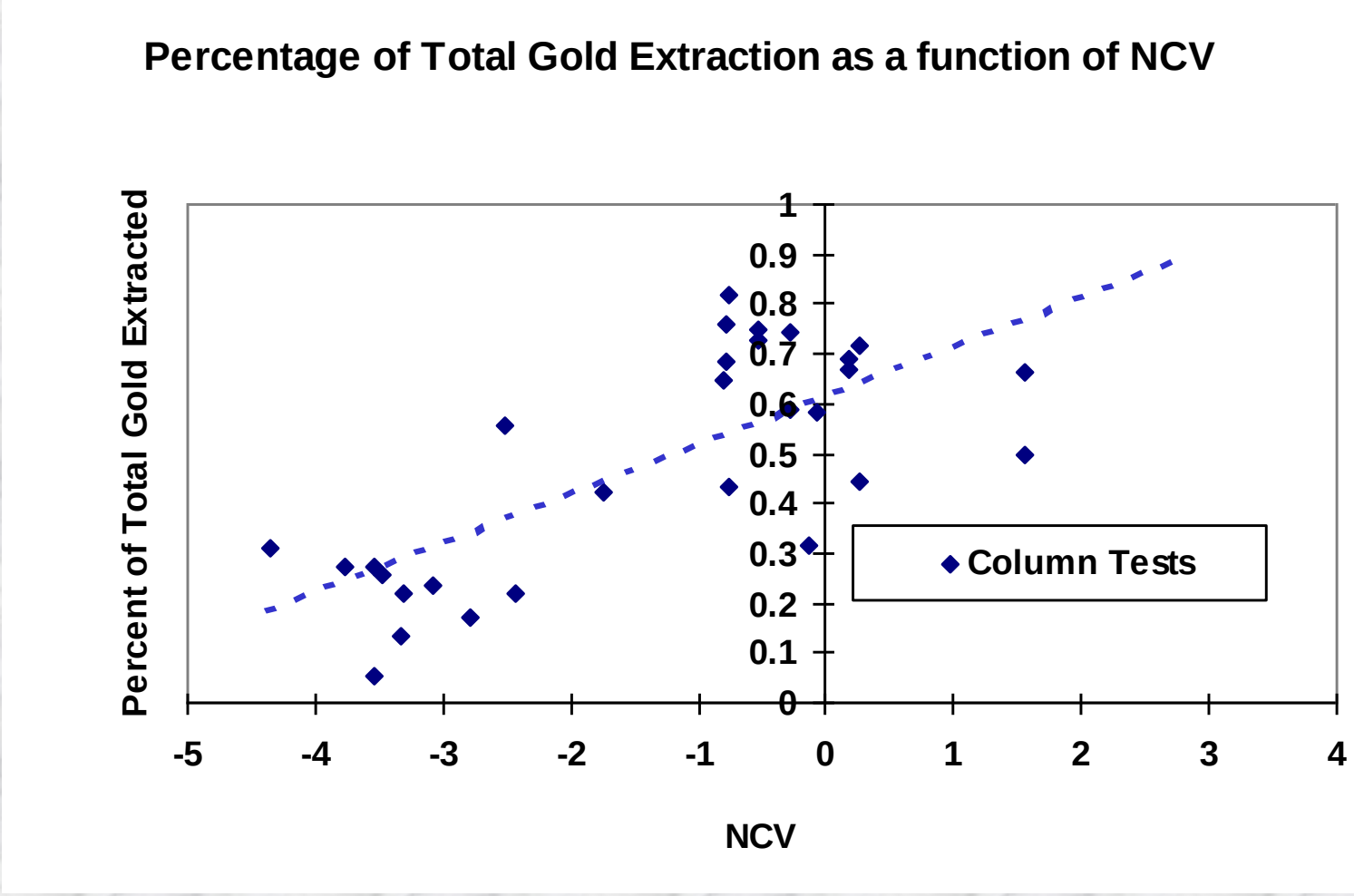
LIME USE AND COLUMN TESTS



CYANIDE USE MODEL



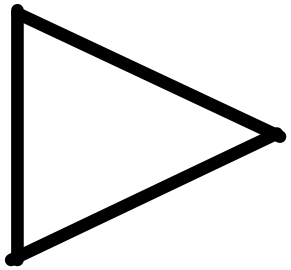
GOLD EXTRACTION AND NCV



BLAST HOLE INFORMATION

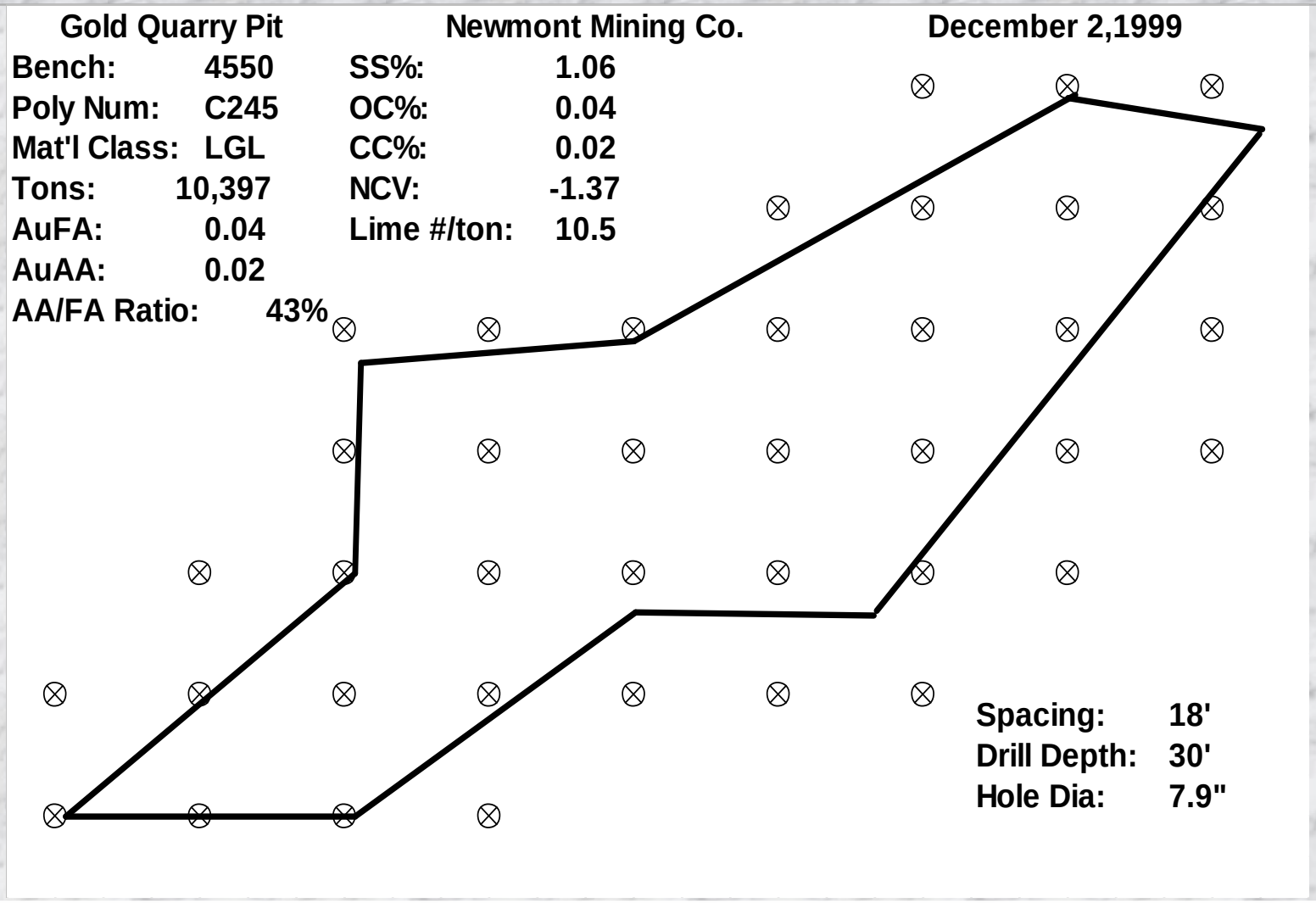
Gold Quarry Blast Hole Information

Class	LGL		Low Recovery General Leach
Drill Hole #	13645		
Series #	99	016	Pattern #
Au Fire Assay [AuFA]	0.031	0.010	CN Extractable Au [AuAA]
Ratio AuCN/AuFA	0.323	0.006	Preg. Rob Value [AuPR]



Total Sulfur [STOT]	1.32	0.06	Total Carbon [CTOT]
Sulfate S [SRO]	0.43	0.05	Organic Carbon [OC]
Sulfide S [SS]	0.89	0.02	Carbonate Carbon [CC]
Fuel Value [FV]	0.96	-1.17	Net Carbonate Value [NCV]

GOLD QUARRY PIT - POLYGON



LIME USE MODEL

- **Net Reaction**
  - **$4\ FeS_2 + 8\ CaO + 15\ O_2 + 6\ H_2O$ ➲ $4\ Fe(OH)_3 + 8\ CaSO_4$**
- **Regression Model – Oxide Ore**
  - **Lime (pounds/ton) = 5.066 - 2.6874 * NCV**
  - **Multiply by Safety Factor: Using S.F. = 2 for NA Stockpiles**

LIME USE MODEL

- **Regression Model – ARD Stockpile Ore**

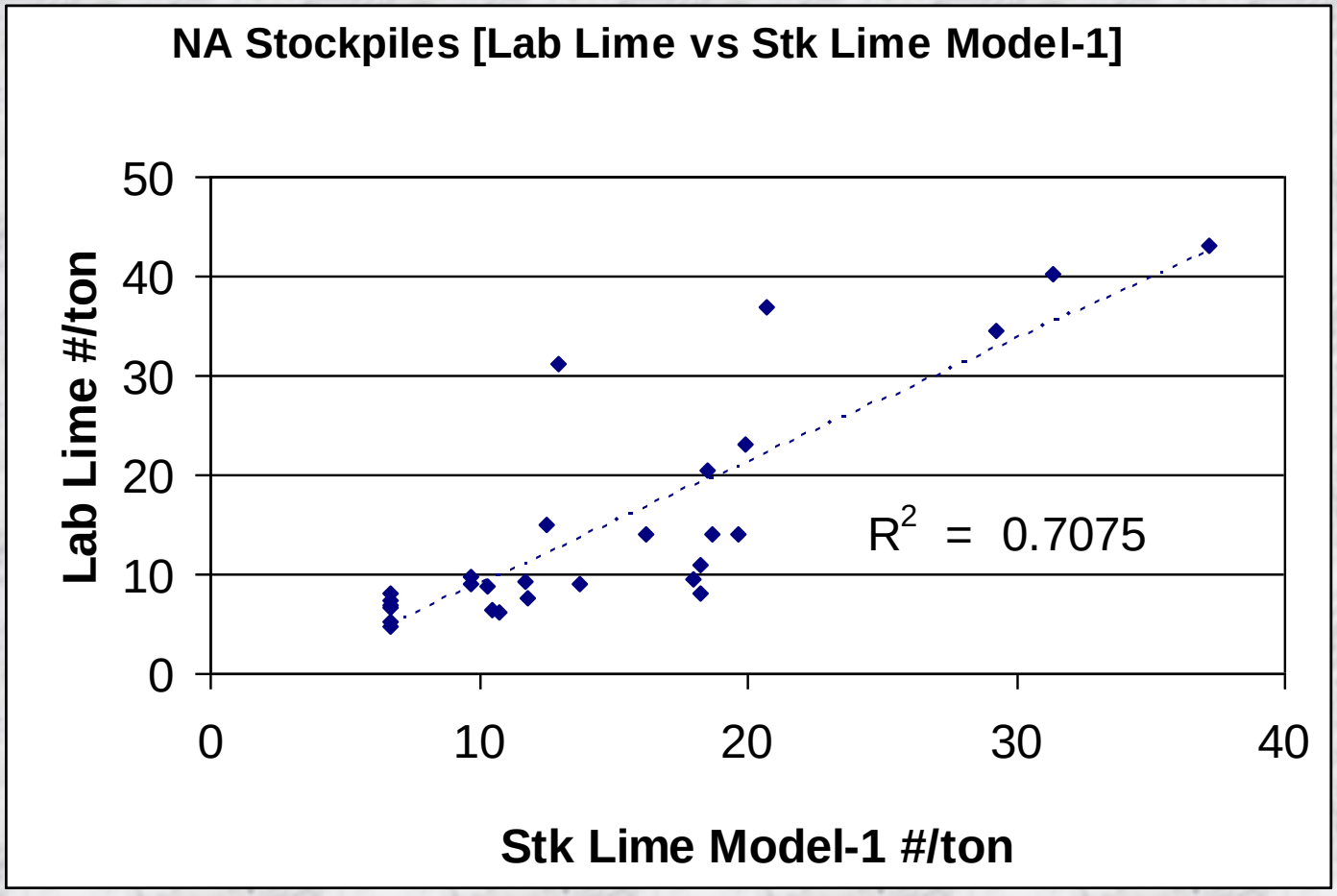
  Lime (pounds/ton) =

  $6.68 – 7.68 * CC^{1.01} + 45.7 * SRO^{1.09}$

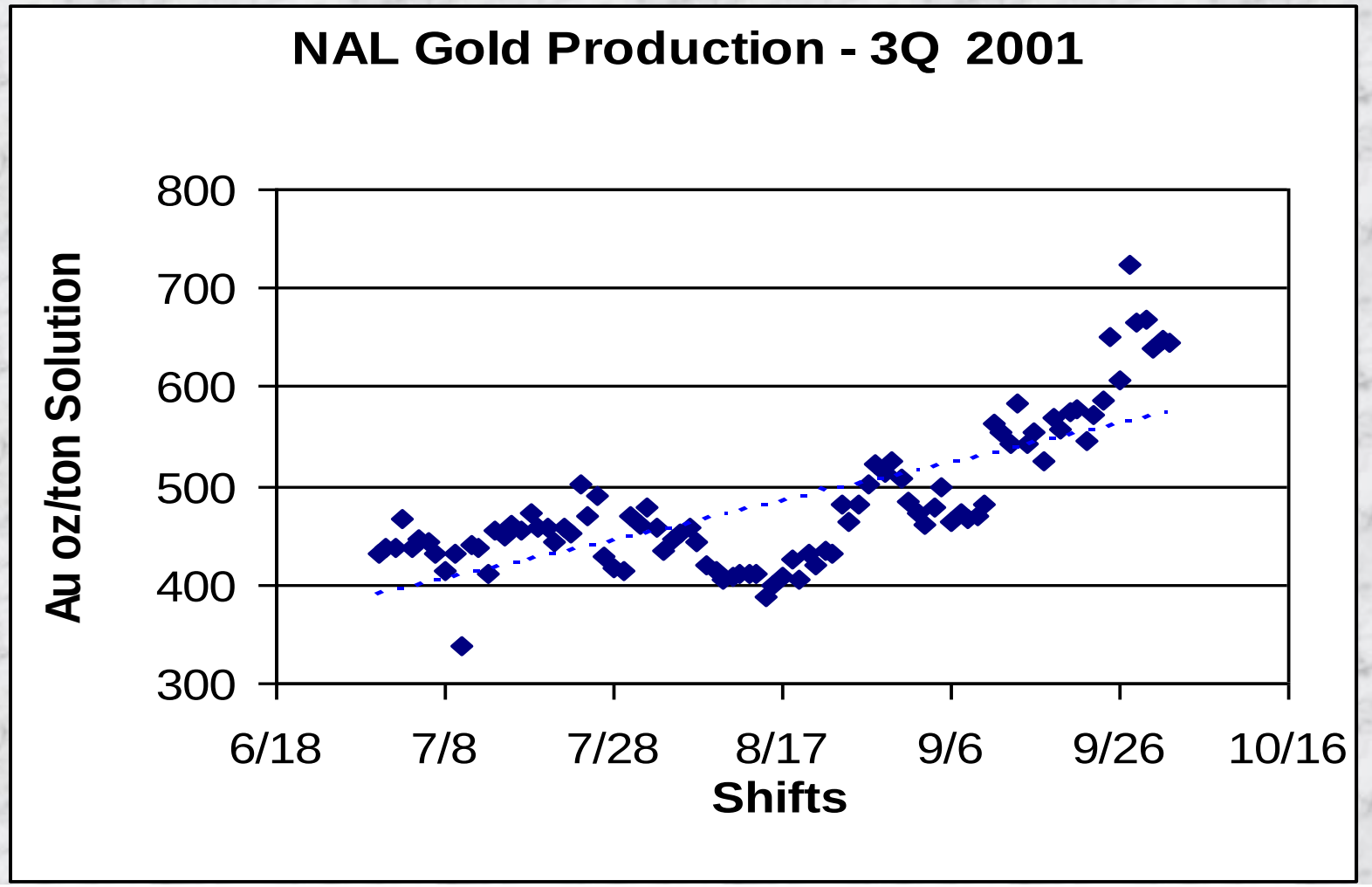
  CC = % Carbonate Carbon

  SRO = % S as SO_4 (Sulfate Sulfur)

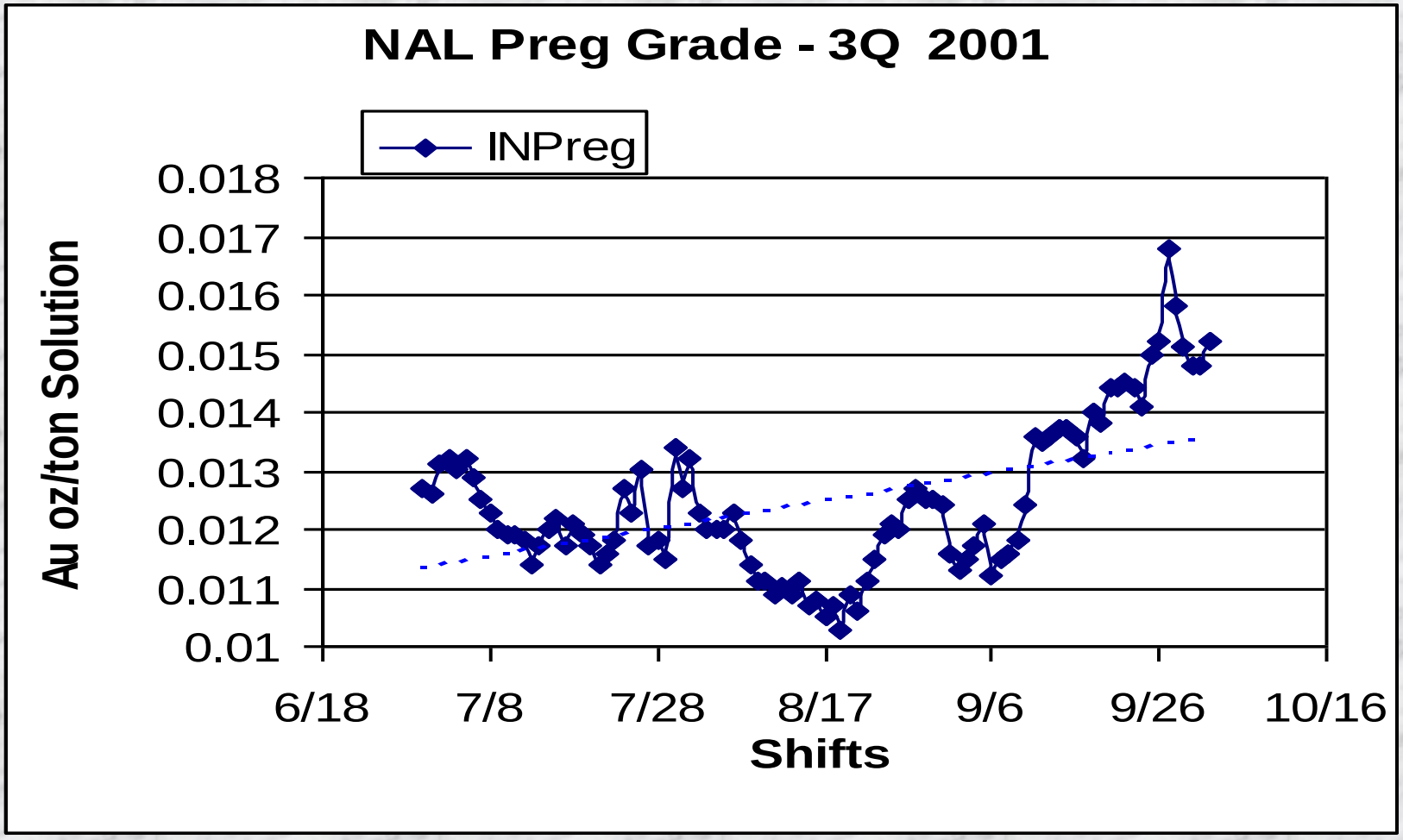
Lime Model for ARD Stockpiles



NAL Gold Production



NAL Solution Grade



Gold Quarry Results

- 2.6 million stockpile tons
- 2.5 million mines tons
- 85,000 recovered Au oz
- Net Revenue
- $ 18,000,000
- 1996 - 1999

CONCLUSIONS

- **Reagent Utilization is Ore Dependant**
- **Run of Mine Ore to have + NCV Value**
- **Biooxidation of Ores with NCV Values less than -2.0**
- **Caustic Cost is 7.5 times higher than Lime**
- **Cyanide Cost is 22 times higher than Lime**
- **Ore Destination by Grade, AA/FA, Preg. Rob and NCV Value**