# ATTACHMENT 19
# STORMWATER CALCULATIONS AND ENGINEERING DRAWINGS
# (APPENDIX F-F OF THE PERMIT APPLICATION)

# F-F WWTU Pick-up System Engineered Drawings and 25-Year 24-Hour Storm Event Calculations

WORLD RESOURCES COMPANY

8113 West Sherman Street
Tolleson, Arizona 85353-4025

Tel: 602.233.9166
Fax: 623.936.9164

March 31, 2014

WJP Engineers
Richard N. Yutko, P.E.
1406 Laurel Boulevard
Pottsville, PA 17901

RE: WWTU Storm Water Pickup Point Construction

Dear Mr. Yutko:

The Arizona facility (AZF) has changed the programmable logic controller for the WWTU storm water pickup points programming. The site plan drawing SP-WWTU 01 was updated with wording to reflect those changes. Please review the following drawing:

Site Plan drawing SP-WWTU 01 Rev 2.2 dated March 31, 2014

After you review the drawing, and any questions you may have are answered, please P.E. stamp this cover letter and the drawing listed above. Please feel free to contact me by cell phone at 602-769-1847, or email at rbellamy@wrcusa.net for any questions or additional requirements you may have.

I have enclosed three cover letters and drawings, along with a flash drive containing the drawings in pdf format, and the CAD drawing is in dwg format. One set will be for you to retain, and please Fedex the two remaining sets, and flash drive, back to the Arizona Facility to my attention.

Respectfully submitted,

Richard L. Bellamy
Maintenance Manager

WORLD RESOURCES COMPANY

8113 West Sherman Street
Tolleson, Arizona 85353-4025

Tel: 602.233.9166
Fax: 623.936.9164

December 31, 2013

WJP Engineers
Richard N. Yutko, P.E.
1406 Laurel Boulevard
Pottsville, PA 17901

RE: WWTU Storm Water Pickup Point Construction

Dear Mr. Yutko:

The Arizona facility (AZF) has installed five storm water pickup points for our facility Wastewater Treatment Unit (WWTU). The storm water is collected on the southern portion of the hazardous waste management unit (HWMU) and then transfered to the holding tanks. Please review the following drawings:

WWTU Storm Water Pickup Detail drawing 13-040-RB Rev 1.0 dated December 30, 2013
WWTU Storm Water Pickup Construction drawing 13-041-RB Rev 1.0 dated December 31, 2013
Site Plan drawing SP-WWTU 01 Rev 2.1 dated December 31, 2013

I have enclosed my supporting documents of details and photo(s) to help with your review of the above drawings.

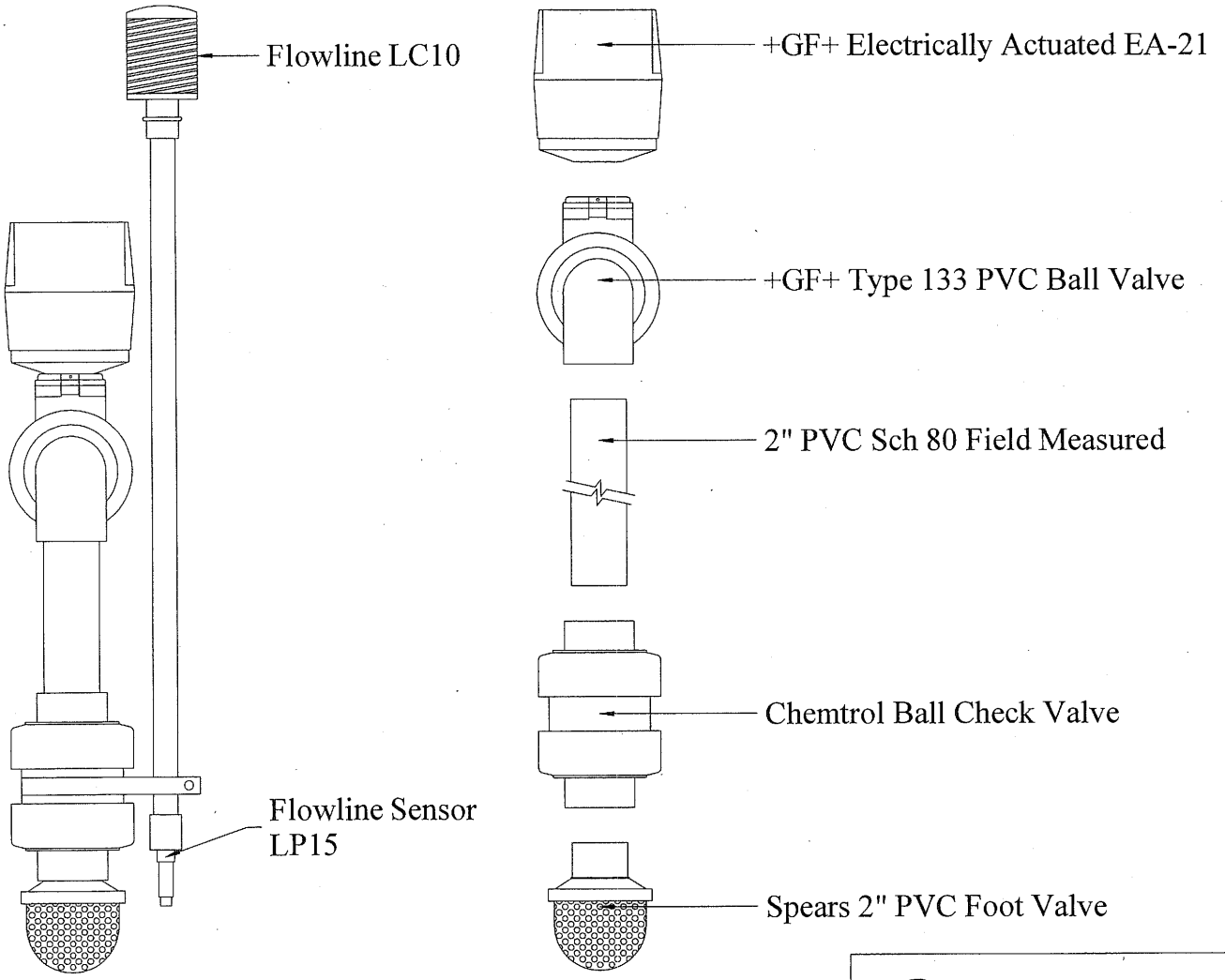
The construction of the components was supervised by me and Jamie Kelleher, (WWTU operator). After you review the drawings, and any questions you may have are answered, please P.E. stamp this cover letter and the drawings listed above. Please feel free to contact me by cell phone at 602-769-1847, or email at rbellamy@wrcusa.net for any questions or additional requirements you may have.

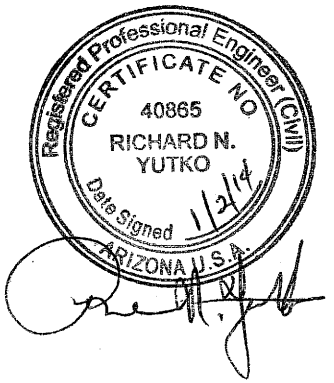
I have enclosed three complete sets of cover letters and drawings, along with a flash drive containing drawings in pdf format, and the CAD drawings in dwg format. One set will be for you to retain, and please Fedex the two remaining sets, and flash drive, back to the Arizona Facility to my attention.

Respectfully submitted,

Richard L. Bellamy
Maintenance Manager

Registered Professional Engineer (Civil)
CERTIFICATE NO
40865
RICHARD N.
YUTKO
Date Signed 1/2/14
ARIZONA U.S.A.



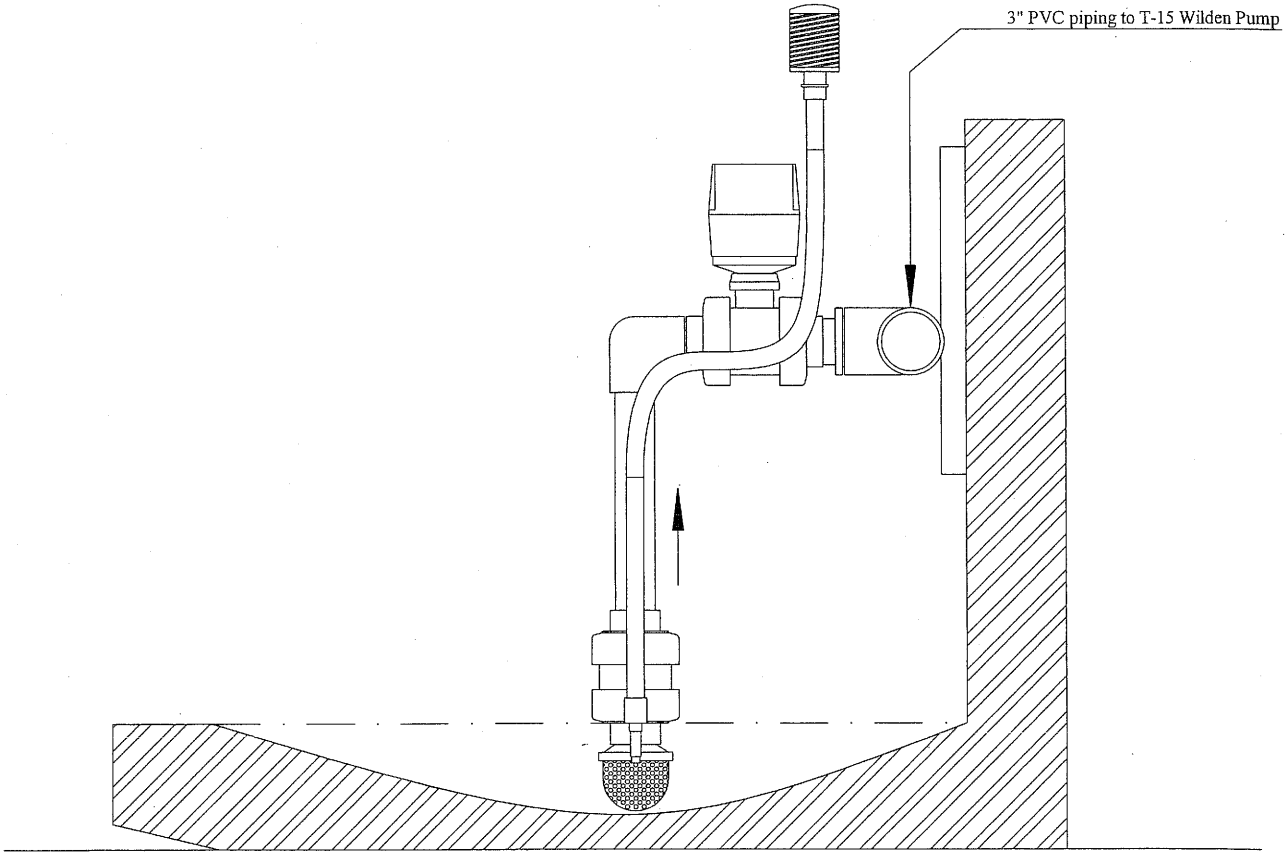

Orginal replacement part that becomes unavilable by the orginal manufacturer an equivalent part can be use as a replacement.

WORLD RESOURCES COMPANY
ISO CERTIFIED RECYCLING FACILITY
8113 W SHERMAN ST. TOLLESON, AZ 85353
602-233-9166 1-800-972-1955

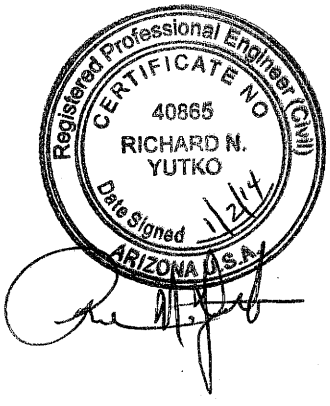
# WWTU Storm Water Pickup Detail



| | | | |
|---|---|---|---|
| SCALE: NTS | DRAWN BY: Richard L. Bellamy | DRAWING NUMBER: 13-040 RB |
| DATE: December 30, 2013 | REVISED REV 1.0 | REVISED BY BY: Richard L. Bellamy |




# Typical Construction of WWTU Storm Water Pickup Points




WORLD RESOURCES COMPANY
ISO CERTIFIED RECYCLING FACILITY
8113 W SHERMAN ST. TOLLESON, AZ 85353
602-233-9166 1-800-972-1955

## WWTU Storm Water Pickup Construction



| | | |
|---|---|---|
| SCALE: NTS | DRAWN BY: Richard L. Bellamy | DRAWING NUMBER: 13-041 RB |
| DATE: December 31, 2013 | REVISED REV 1.0 | REVISED BY BY: Richard L. Bellamy |

World Resources Company

**SITE PLAN SP-WWTU 01**

* Wastewater Treatment Unit (WWTU)
Storm water pickup point on HWMU

WWTU Storm Water Pickup; The Flowline sensors detect storm water presents and send a signal to the WWTU Programmable Logic Controller (PLC). The PLC actuate ball valve(s) and start a diaphragm pump(s) to siphon water from the HWMU, and transfer to one of WWTU raw water holding tanks. The PLC will open and close the storm water pickup point ball valves based on the water at the location.

N

0 40 80 160

APPOXIMATE SCALE IN FEET

BERM

BLOCK WALL

FENCE

RAILROAD TRACK

SuperSpan MESH CANOPY

8113 West Sherman Street

Railroad Spur

Bulk Shipping

Electric Transformer

Administration & Laboratory Building

Hazardous Waste Management Unit (HWMU)

Parking Lot

Lab Check In Station

MW-9

Bulk/Non-Bulk Receiving B

Certified Bag/Drum Scale

Wash Station

MW-6 (DRY)

Certified Truck Scale

Parking Lot

Radiation Detector

MW-7 (DRY)

Manifest/Shipping Check In Station

EMPLOYEES SHOWER BUILDING

Locker Station

Tools/Parts Storage

Maintenance Supp

Control Room

Bulk/Non-Bulk Receiving A

Mechanical Shredding/ Size Reducer Unit

Mechanical Blender

Particle Collector

Thermal Concentrating Unit (TCU)

Secondary Filters

Supply Shed

Diesel

Agglomerate Agent Tanks

Oils

Gravel Road

Parshal Flume

MW-10

WWTU-Wastewater Treatment Unit

Mix Tank

Filter Press

Holding Tank-1

Holding Tank-2

Holding Tank C

Holding Tank B

Holding Tank A

Carbon Columns

Resin Columns

PLC

NW Holding Tank

SW Holding Tank

MW-11

Gravel

Equipment Storage

Equipment Storage

Storm water Drainage Area

Gravel

Bag Scale

CBS Station

Asphalt

Asphalt

Registered Professional Engineer (Civil)
CERTIFICATE NO
40865
RICHARD N.
YUTKO
Date Signed 4/21/14
ARIZONA U.S.A.

**WWTU Storm Water Network**

Created: May 1, 1997;
Revision 2.2; March 31, 2014

# Technical Memorandum

201 E. Washington St. Suite 500
Phoenix, AZ 85004

T: 602.567.4000
F: 602.567.4001

Prepared for: World Resources Company

Project Title: RCRA Permit Support

Project No.: 143503.001

Subject: Revised Response to ADEQ Comment No. 10

Date: May 16, 2014

To: Ms. Kimberly Myers
Manager of Environmental, Health & Safety Affairs
World Resources Company - Arizona Facility

From: Larry B. Williams, P.E.

Prepared by: _____
Joshua Sanders, Arizona P.E. License No. 41965, Expires 3/31/2017

Reviewed by: _____
Larry B. Williams, P.E.


*Limitations:*

*This document was prepared solely for World Resources Company in accordance with professional standards at the time the services were performed and in accordance with the contract between World Resources Company and Brown and Caldwell dated October 16, 2012. This document is governed by the specific scope of work authorized by World Resources Company; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by World Resources Company and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.*

This Revised Technical Memorandum (Tech Memo) describes an evaluation of stormwater management features at the World Resources Company (WRC) Hazardous Waste Management Unit (HWMU) located at 8113 West Sherman Street, Tolleson, Arizona 85353. The evaluation is in response to the Arizona Department of Environmental Quality's (ADEQ's) comments 10a and 10b, Control of Leachate and Run-off, regarding the containment volume of the HWMU; the volume of stormwater resulting from a 25-year, 24-hour storm event; and the time required to remove stormwater from a 25-year, 24-hour storm event.

## 1. Hazardous Waste Management Unit

The HWMU is a large open work area that has fabric canopy, as described below, to protect the work area from wind and a sealed concrete floor to prevent liquids from migrating into the soil beneath the floor. Surrounding the floor is a short concrete block wall, which is connected in some areas to an inward-sloping concrete/asphalt apron with an outer curb. Collectively, the above-described containment system serves to prevent stormwater run-on from entering the HWMU and to contain precipitation that falls onto the apron or into the HWMU until the water can be removed and processed in WRC's Wastewater Treatment Unit (WWTU). In the original version of this Tech Memo, dated August 5, 2013, the wall was used to calculate the HWMU containment capacity. This Revised Tech Memo provides a recalculated HWMU containment capacity based on the additional storage capacity available between the wall and apron curb. Attachment 1 includes Site Plan SP-WWTU 01, which shows the WRC facility, including the HWMU and WWTU. As shown on SP-WWTU 01, the HWMU is covered by a fabric canopy. The canopy is approximately 22 feet above the HWMU floor and extends to the floor along the sides of the HWMU. For purposes of this evaluation, the canopy is assumed not to prevent precipitation from entering the HWMU.

## 2. Containment Calculations

Attachment 2 includes an HWMU site plan (Site Plan – H.W.M.U. Elevations), sealed and signed by Steve R. Lewis, P.E, on June 5, 2013. The site plan indicates a 10-foot apron outside of and abutting the concrete block wall on all sides of the HWMU, except for the north side. On the north side, the apron extends approximately 5 feet north of the wall but only between the wall and the maintenance building. The outer portions of the aprons are higher than the inner concrete block wall and are designed to drain direct precipitation into the inner portion of the HWMU. The aprons thus increase the area of the HWMU to receive direct precipitation. From the outer edges of the aprons, the HWMU extends 582.6 feet from east to west and 312.6 feet from north to south and covers approximately 4.18 acres. In contrast, the inside dimensions of the HWMU are approximately 305 feet x 565 feet, or approximately 3.96 acres. Elevations shown on the site plan indicate that the potential for run-on into the HWMU is minimized by the concrete block wall located along the northern portion of the HWMU, stormwater drain inlets north of the wall, surface features that direct stormwater flow to the inlets, and drainage channels along the east and west sides of the HWMU which convey stormwater runoff to a stormwater retention area near the southern edge of WRC's property.

Attachment 3 is a copy of the HWMU site plan (HWMU -- Apron Elevation Details) that combines original survey data with elevation data associated with the apron and apron curb. Elevation contours have been added to the plan. In addition, Attachment 3 includes three cross-sections depicting the concrete floor, wall, and apron curb. Detailed elevations of the HWMU concrete floor shown on the site plan indicate that the floor is generally higher in the eastern portion than in the western portion and generally lower in the southern portion than in the northern portion. Top elevations of the wall are shown on the site plan as "TW" (top of wall) elevations. Top elevations for the apron curb are shown on the site plan as "TC"(top of curbing) elevations. Based on the TC elevations, stormwater would not overtop the southernmost berm, but instead be contained up to an elevation of 14.23 feet. This elevation corresponds to the lowest point on the north side of the HWMU, which corresponds to the top of the Bulk/No Bulk Loading Area Ramp. AutoCAD® Civil

3D® was used to estimate the HWMU volume between the base elevation contour map and an elevation of 14.23 feet. In the model, 14.23 feet was assumed to be the comparison surface and the base contour map was called the "new surface" such that the "Cut" volume shown in the AutoCAD® Civil 3D® output represents the volumetric capacity of the HWMU. The AutoCAD® Civil 3D® model calculated a total containment capacity of 6,744.7 cubic yards. Based on a maximum permitted HWMU capacity of 4,750 cubic yards of recyclable materials, the HWMU has approximately 1,994.7 cubic yards of excess capacity. This is equivalent to approximately 402,850 gallons of available capacity for stormwater collection. Attachment 4 is a copy of the AutoCAD® Civil 3D® output.

### 3. 25-Year, 24-Hour Storm Event

Attachment 5 includes calculations that indicate approximately 335,605 gallons of stormwater would accumulate on the HWMU floor as a result of a precipitation from a 25-year, 24-hour storm event falling directly into the HWMU and onto the aprons that drain into the HWMU. Therefore, a 25-year, 24-hour storm event would occupy a volume of 1,661.7 cubic yards. Section 3.4 and Table 3.2 of the Drainage Design Manual for Maricopa County, Hydrology, referenced in the Attachment 4 calculations, are included in Attachment 6.

### 4. Stormwater Removal Time

WRC reports that in the past it would rent a 7,000 gallon per hour (GPH) pump and portable 21,000-gallon Frac tanks during significant storm events to supplement existing on-site equipment as needed to pump stormwater out of the HWMU and store it prior to on-site treatment. The existing WWTU equipment includes a 5,000-GPH pump, storage tanks with a capacity of 110,000 gallons, and the treatment tanks and vessels. The WWTU has a permitted capacity of 90,000 gallons per day (GPD) but 1,000 GPD are generated during normal operations. Thus, 89,000 GPD would be available for stormwater treatment. WRC has reported a change in procedures that would call for the rental of a second 7,000-GPH pump and additional tanks as necessary to achieve its goal of removing from the HWMU all stormwater resulting from a 25-year, 24-hour storm event during essentially the same period as the storm event. The calculations shown in Attachment 4 indicate that the goal can be met with a combined pump capacity of 19,000 GPH because that capacity would optimally allow the volume estimated to result from a 25-year, 24-hour storm event (335,605 gallons) to be removed in 17.7 hours. The actual removal time will vary but will always be more than 17.7 hours, which is the minimum theoretically possible removal time. WRC has developed procedures to ensure that stormwater will be removed without undue delay. WRC's description of its procedures, presented below, includes its assessment that the 25-year, 24-hour storm event volume of 335,605 gallons can be realistically expected to be removed within 40 hours.

The following provides a general outline of the process used by WRC for making decisions to commence activities related to a large storm and for deciding on the required pumps, tanks and personnel to handle an event.

> Weather stations and radar tracking systems are monitored by WRC personnel when Phoenix is predicted to receive rain during normal facility operating hours. During the weekend, the facility is inspected daily. If greater than 1/10 of an inch of water is present at any of the five pick-up points located along the south containment wall, the Emergency Coordinator will be notified, who in turn will mobilize the appropriate personnel to ensure the automatic system discussed below is removing stormwater, and to determine if additional resources are required (i.e., pumps or additional tanks). If a storm event occurred between these weekend inspections, there may be a period of time when water is not being removed, dependent on the status of tank availability; however, the next inspection or the next routine work day would trigger the

mobilization of appropriate personnel to ensure the system is collecting the stormwater, and to make the determination if additional resources are required (i.e., pumps or additional tanks).

As stated in Section 4 of WRC's Resource Conservation and Recovery Act (RCRA) permit application, the sensors automatically detect the presence of water and send a signal to the programmable logic controller, which opens two of the five actuated ball valves, starting an air diaphragm pump to remove stormwater from the HWMU, transferring it to one of the WWTU raw water tanks. The WWTU raw water tanks can hold 80,000 gallons if completely empty, and it would take approximately 16 hours of continual pumping to collect this volume, with an additional 1-2 hours required for manual valve line-up to the various tanks. It should be noted that the Brown and Caldwell calculation used the pump's rated capacity, but WRC does not pump at that rated capacity due to the added stress and wear placed on the equipment.

If a storm event occurs, and it is expected that the WWTU's raw water tank capacity is not sufficient to remove all of the expected volume of stormwater, the Frac tanks and an additional pump can be delivered within 3-4 hours of notification. To contain the 25-year, 24-hour storm event volume and depending on the WWTU's available volume, WRC would require 13-17 Frac tanks. These tanks have a 21,000-gallon capacity, although they are not filled to total capacity to prevent over-filling. Accounting for delivery time of the tanks and additional pump, using the WWTU transfer pump to transfer stormwater out of the WWTU and into Frac tanks, the WWTU pick-up pump pumping from the HWMU into the raw water tanks, the rental pump pumping directly from the HWMU into the Frac tanks, and personnel available for manual switching of valves and lines, WRC realistically expects to be able to remove the 25-year, 24-hour storm event volume of 335,605 gallons within 40 hours.

In the event of a storm lasting longer than 24 hours, additional tanks will be requested to store the additional stormwater and pumping will continue following same procedure outlined above.

## 5. Conclusion

The attached calculations and supporting information indicate that the total estimated volumetric capacity of the HWMU (6,744.7 cubic yards) is sufficient to contain the maximum permitted quantity of recyclable materials (4,750 cubic yards) plus precipitation from a 25-year, 24-hour storm event (equivalent to 1,661.7 cubic yards). Additionally, the combination of equipment owned and rented by WRC provides a combined pump capacity of 19,000 GPH, which would allow 335,605 gallons to be pumped from the HWMU within 40 hours, thereby minimizing the potential for stormwater accumulations in the HWMU.

# Attachment 1: Site Plan WWTU 01

World Resources Company

# SITE PLAN SP-WWTU 01

* Wastewater Treatment Unit (WWTU)
Storm water pickup point on HWMU

**WWTU Storm Water Pickup; The Flowline sensors detect storm water presents and send a signal to the WWTU Programmable Logic Controller (PLC). The PLC actuate ball valve(s) and start a diaphragm pump(s) to siphon water from the HWMU, and transfer to one of WWTU raw water holding tanks. The PLC will open and close the storm water pickup point ball valves based on the water at the location.**

N

0 40 80 160

APPOXIMATE SCALE IN FEET

BERM

BLOCK WALL

FENCE

RAILROAD TRACK

SuperSpan MESH CANOPY

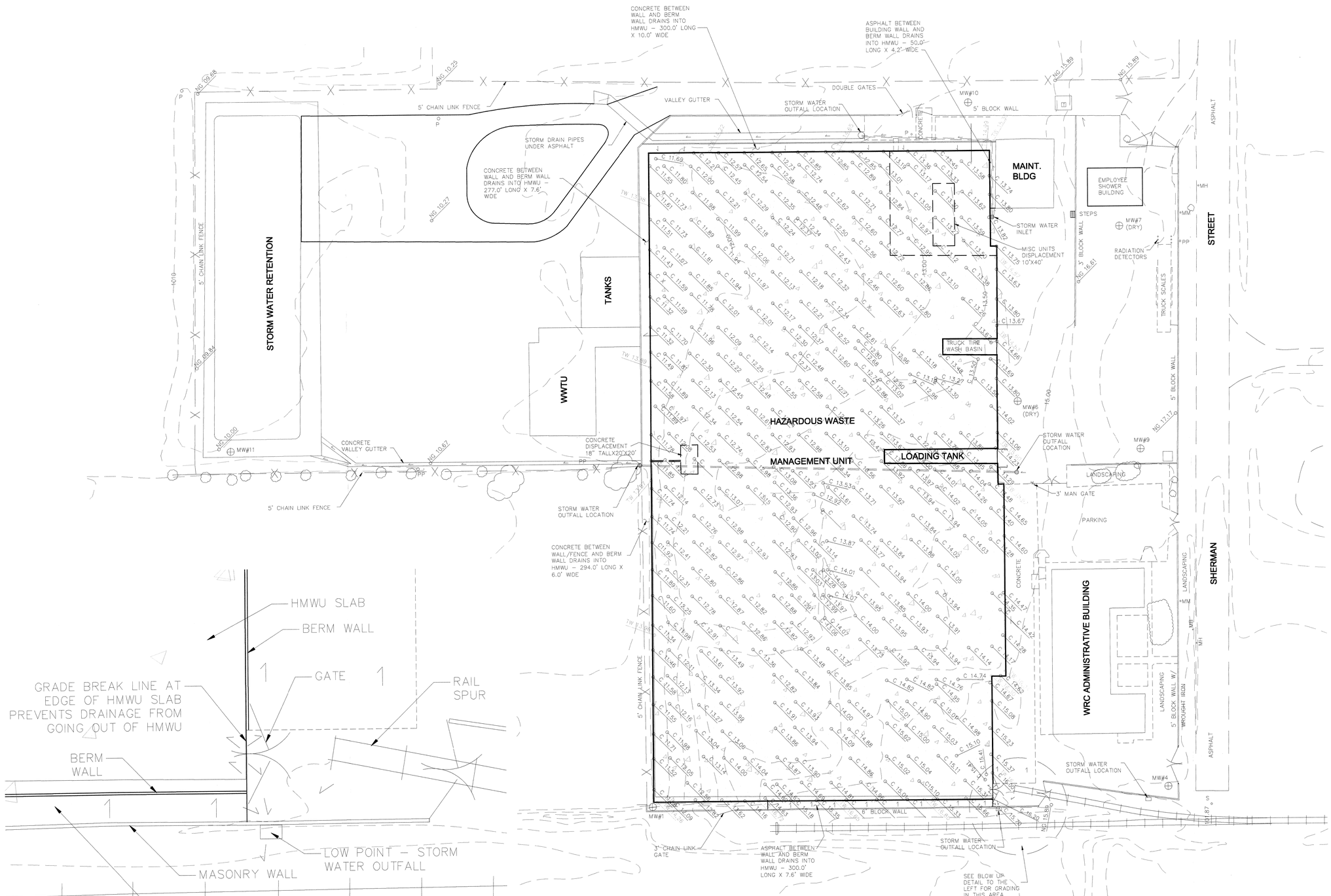
8113 West Sherman Street

Railroad Spur
Bulk Shipping
Electric Transformer
Administration & Laboratory Building
Hazardous Waste Management Unit (HWMU)
Porking Lot
Lab Check in Station
MW-9
MW-6 (DRY)
Certified Truck Scale
Parking Lot
Radiation Detector
MW-7 (DRY)
Manifest/Shipping Check in Station
EMPLOYEES SHOWER BUILDING
Locker Station
Tools/Parts Storage
Maintenance Shop
Control Room
Bulk/Non-Bulk Receiving B
Certified Bag/Drum Scale
Bulk/Non-Bulk Receiving A
Mechanical Shredding/ Size Reducer Unit
Mechanical Blender
Particle Collector
Thermal Concentrating Unit (TCU)
Secondary Filters
Supply Shed
Diesel
Agglomerate Agent Tanks
Oils
Gravel Road
Parshal Flume
MW-10
Wash Station
WWTU-Wastewater Treatment Unit
Mix Tank
Filter Press
Holding Tank-1
Holding Tank-2
Holding Tank-A
Holding Tank-B
Holding Tank-C
Carbon Columns
Resign Columns
PLC
NW Holding Tank
SW Holding Tank
Asphalt
MW-11
Gravel
Equipment Storage
Equipment Storage
Storm water Drainage Area
Gravel
Bag Scale
CBS Station
Asphalt

Registered Professional Engineer (Civil)
CERTIFICATE NO
40865
RICHARD N. YUTKO
Date Signed 4/2/14
ARIZONA U.S.A.

**WWTU Storm Water Network**
Created: May 1, 1997;
Revision 2.2; March 31, 2014

# Attachment 2: Site Plan – H.W.M.U. Elevations







BLOW-UP DETAIL FOR RAIL SPUR ENTRY AT NEC OF THE HMWU (1"=10')

**LEGEND**

| | |
|---|---|
| PP | POWER POLE |
| | LAMP POST |
| | CMU WALL |
| CONC. | CONCRETE |
| | ASPHALT |
| P | POLE |
| MB | MAILBOX |
| WM | WATER METER |
| MH | SEWER MANHOLE |
| TW | TOP OF WALL |
| T | ELECTRICAL TRANSFORMER |

**BENCHMARK:**

MCDOT CONTROL POINT 44D1
ELEVATION = 1127.00 (NAVD 88)
ELEVATION = 1124.26 (NGVD 29)

CALCULATED DIFFERENCE = 2.74'

34589
STEVE R. LEWIS
Date Signed 6-5-13
ARIZONA, U.S.A.
Expires 3/31/2015

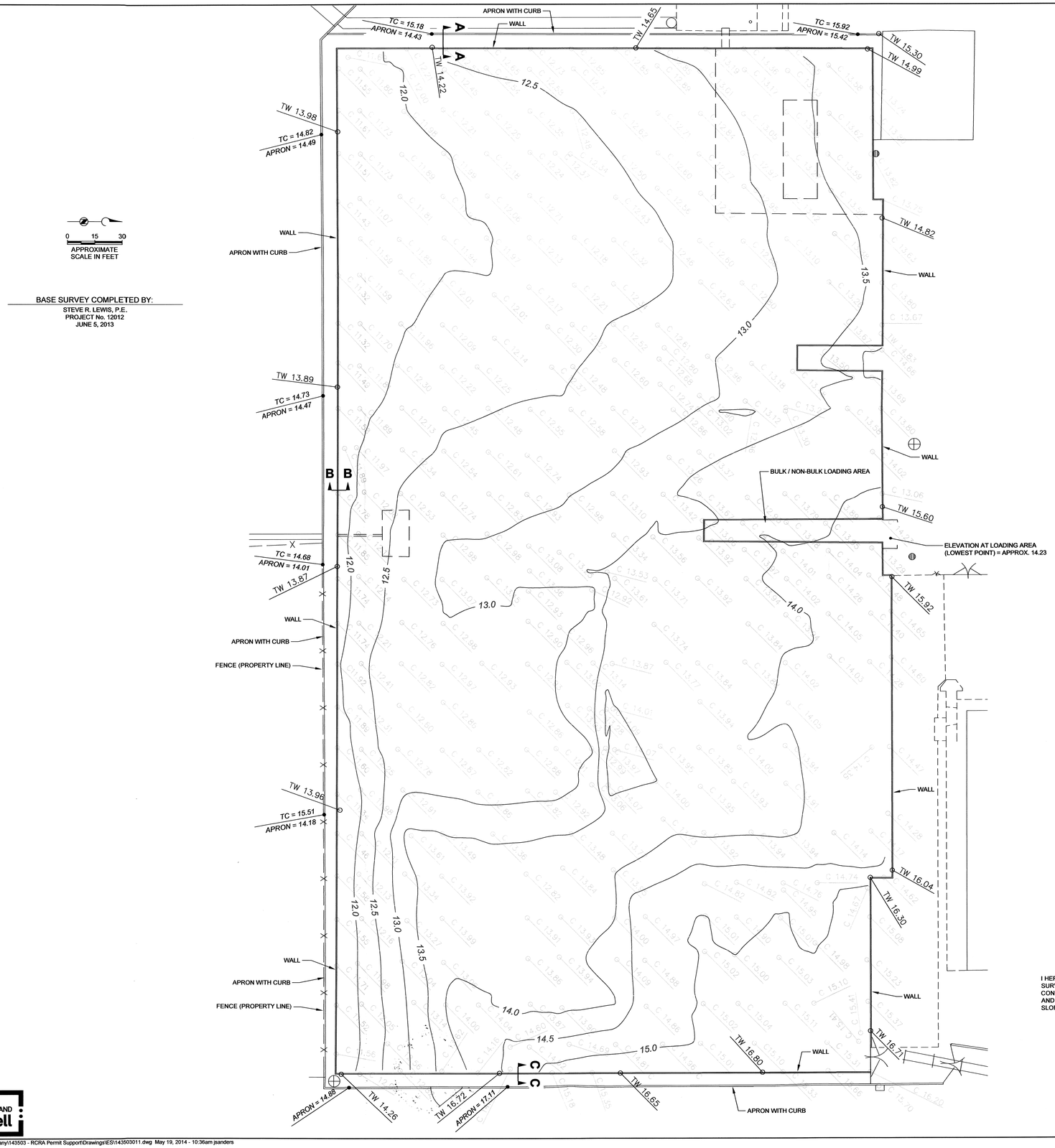
6/5/13

STEVE R. LEWIS, PE
8340 W. VOGEL AVE. PEORIA, AZ. 85345 PHONE: (602) 570-1099

SITE PLAN – H.W.M.U. ELEVATIONS
WORLD RESOURCES COMPANY
8113 W. SHERMAN STREET, TOLLESON, AZ 85353

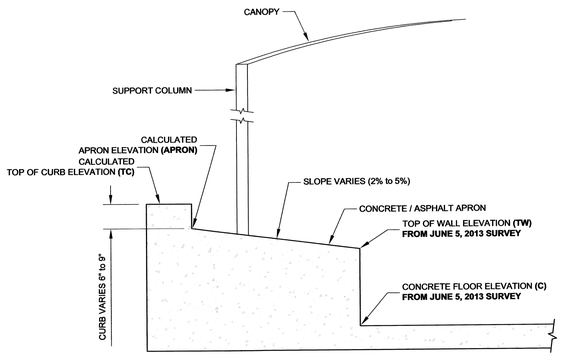
DRAWN BY: GP/SRL
START DATE: 7/6/13
DN: BASE01.DWG
PROJECT NO.: 12012

# Attachment 3: HWMU – Apron Elevation Details

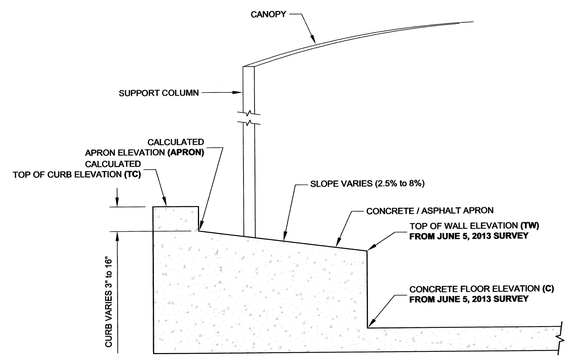



0 15 30
APPROXIMATE
SCALE IN FEET

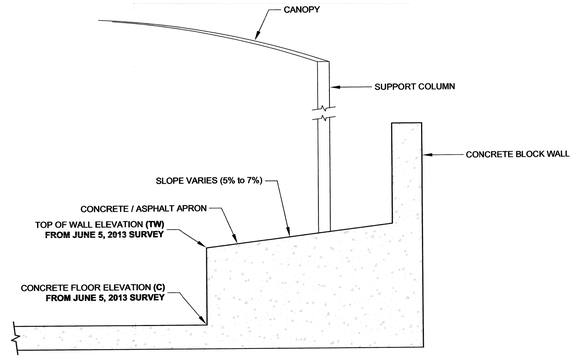
BASE SURVEY COMPLETED BY:
STEVE R. LEWIS, P.E.
PROJECT No. 12012
JUNE 5, 2013




SECTION A-A
NOT TO SCALE




SECTION B-B
NOT TO SCALE




SECTION C-C
NOT TO SCALE

I HEREBY CERTIFY THAT THE DRAWING MEASUREMENTS SHOWN HEREON WERE BASED ON INFORMATION RECEIVED FROM THE SURVEY "SITE PLAN - H.W.M.U ELEVATIONS" PREPARED BY STEVE R. LEWIS DATED JUNE 5, 2013 BUT WERE NOT INDEPENDENTLY CONFIRMED BY A FIELD VERIFICATION OR INVESTIGATION OF THE GRADES AND ARE CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF. APRON ELEVATIONS AND TOP OF CURB ELEVATIONS SHOWN HEREON WERE CALCULATED USING FIELD MEASURED SLOPE AND DISTANCES IN RELATION TO TOP OF WALL ELEVATIONS PROVIDED ON THE JUNE 5, 2013 SURVEY.

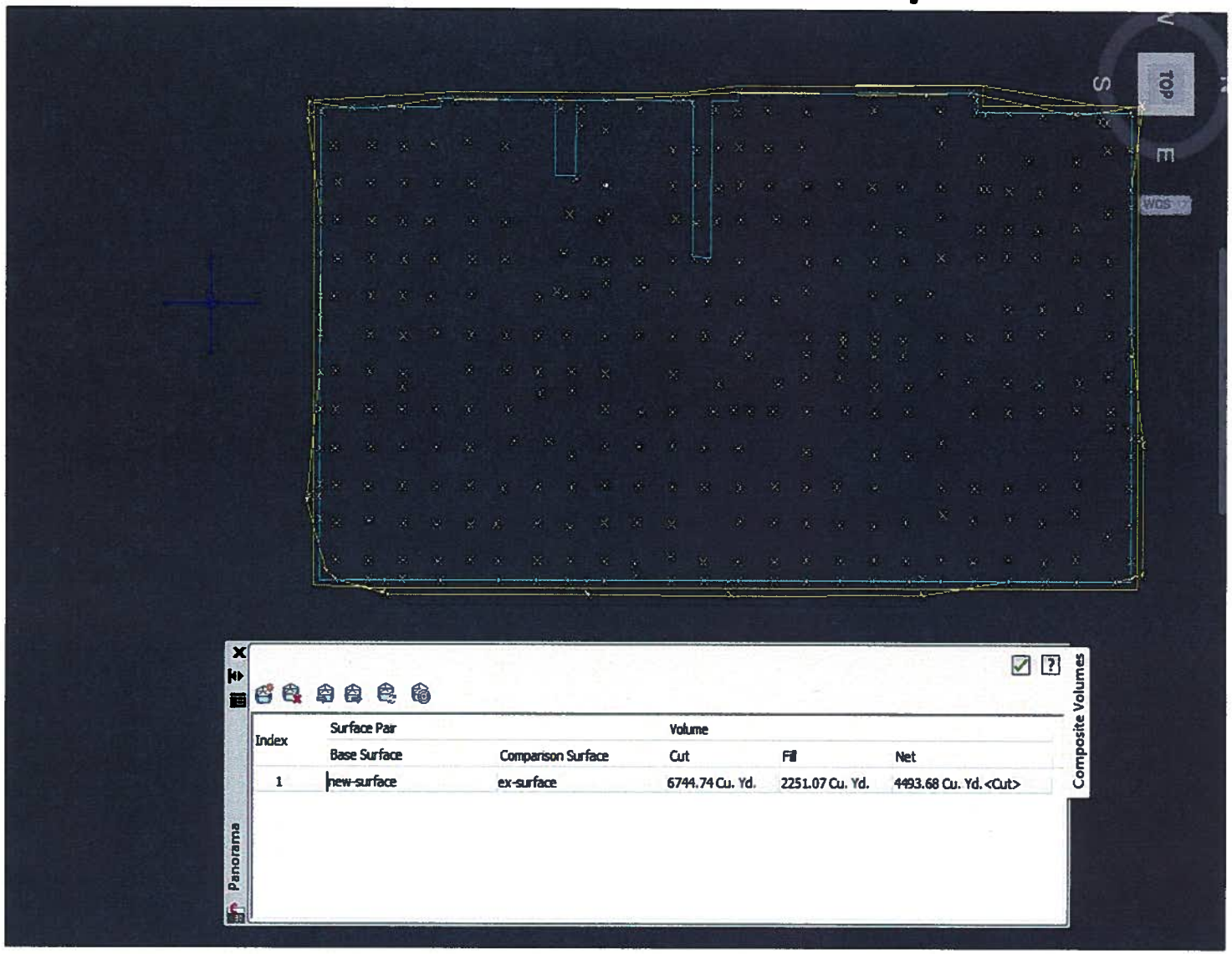
Registered Professional Engineer (Civil)
CERTIFICATE NO.
41965
JOSHUA G.
SANDERS
5/14/14
Date Signed
ARIZONA U.S.A.
Expires 3/31/17

Attachment 3
# HWMU
# APRON ELEVATION DETAILS
WORLD RESOURCES COMPANY
TOLLESON, ARIZONA

Brown AND Caldwell

# Attachment 4: AutoCAD® Civil 3D® Output

# AutoCAD® 3D® Output




APPENDIX F-F

# Attachment 5: Stormwater Calculations

STORM WATER RUNOFF VOLUME FOR THE 25-YEAR, 24-HOUR STORM EVENT

References:

Drainage Design Manual for Maricopa County, Hydrology (DDMMC)

Site Plan – H.W.M.U. Elevations by Steve R. Lewis, PE, 3/28/2013

Equation:

V = c (P/12) A (DDMMC section 3.4 Volume Calculations)

where:

V = calculated runoff volume, in acre-ft

C = runoff coefficient (0.95 – maximum coefficient in DDMMC Table 3.2 for impervious surface)

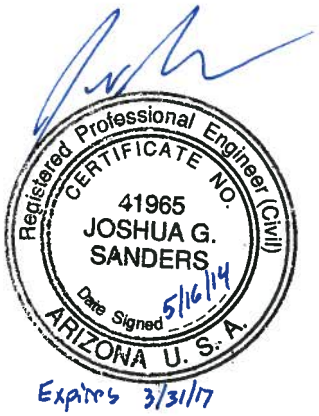
P = rainfall depth, in inches (3.1 from DDMMC Figure A.11)

A = drainage area, in acres (approximately 312.6 ft x 582.6 ft = 4.18 acres)

V = 0.95 (3.1/12) 4.18

= 1.03 acre-ft or 44,867 CF

= 335,605 gallons



MAXIMUM TIME NEEDED TO REMOVE STORM WATER RUNOFF FROM THE 25-YEAR, 24-HOUR STORM EVENT

References:

Pump rates provided by WRC

Total pump capacity – 19,000 gallons per hour

Volume for 25-yr, 24-hr storm event – 335,605 gallons

Time needed = 335,605 gallons x 1 hr / 19,000 gallons

= 17.7 hours

# Attachment 6: Excerpts from Drainage Design Manual for Maricopa County, Hydrology

## 3.3 ASSUMPTIONS

Application of the Rational Equation requires consideration of the following:

1. The peak discharge rate corresponding to a given intensity would occur only if the rainfall duration is at least equal to the time of concentration.
2. The calculated runoff is directly proportional to the rainfall intensity.
3. The frequency of occurrence for the peak discharge is the same as the frequency for the rainfall producing that event.
4. The runoff coefficient increases as storm frequency decreases.
5. The watershed should be of uniform land use. For example, sub-basins with both natural (undeveloped) and developed land uses should be broken into separate sub-basins where possible.

## 3.4 VOLUME CALCULATIONS

Volume calculations should be done by applying the following equation:

$$V = C\left(\frac{P}{12}\right)A \qquad (3.3)$$

where:

$V$ = calculated volume, in acre-feet.

$C$ = runoff coefficient from Table 3.2.

$P$ = rainfall depth, in inches.

$A$ = drainage area, in acres.

In the case of volume calculations for stormwater storage facility design, $P$ equals the 100-year, 2-hour depth, in inches, as discussed in Section 2.2, and is determined from Figure A.56 of Appendix A.1.

## 3.5 LIMITATIONS

Application of the Rational Method is appropriate for watersheds less than 160 acres in size. This is based on the assumption that the rainfall intensity is to be uniformly distributed over the drainage area at a uniform rate lasting for the duration of the storm. The Maricopa County Unit Hydrograph Procedure described in Chapter 5 may also be used for areas less than 160 acres where hydrograph routing is desired, or in cases where the Rational Method assumptions do not apply.

## Table 3.2
### RUNOFF COEFFICIENTS FOR MARICOPA COUNTY

| Land Use Code | Land Use Category | Runoff Coefficients by Storm Frequency[1, 2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2-10 Year | | 25 Year | | 50 Year | | 100 Year | |
| | | min | max | min | max | min | max | min | max |
| VLDR | Very Low Density Residential[3, 4] | 0.33 | 0.42 | 0.36 | 0.46 | 0.40 | 0.50 | 0.41 | 0.53 |
| LDR | Low Density Residential[3, 4] | 0.42 | 0.48 | 0.46 | 0.53 | 0.50 | 0.58 | 0.53 | 0.60 |
| MDR | Medium Density Residential[3, 4] | 0.48 | 0.65 | 0.53 | 0.72 | 0.58 | 0.78 | 0.60 | 0.82 |
| MFR | Multiple Family Residential[3, 4] | 0.65 | 0.75 | 0.72 | 0.83 | 0.78 | 0.90 | 0.82 | 0.94 |
| I1 | Industrial 1[3] | 0.60 | 0.70 | 0.66 | 0.77 | 0.72 | 0.84 | 0.75 | 0.88 |
| I2 | Industrial 2[3] | 0.70 | 0.80 | 0.77 | 0.88 | 0.84 | 0.95 | 0.88 | 0.95 |
| C1 | Commercial 1[3] | 0.55 | 0.65 | 0.61 | 0.72 | 0.66 | 0.78 | 0.69 | 0.81 |
| C2 | Commercial 2[3] | 0.75 | 0.85 | 0.83 | 0.94 | 0.90 | 0.95 | 0.94 | 0.95 |
| P | Pavement and Rooftops | 0.75 | 0.85 | 0.83 | 0.94 | 0.90 | 0.95 | 0.94 | 0.95 |
| GR | Gravel Roadways & Shoulders | 0.60 | 0.70 | 0.66 | 0.77 | 0.72 | 0.84 | 0.75 | 0.88 |
| AG | Agricultural | 0.10 | 0.20 | 0.11 | 0.22 | 0.12 | 0.24 | 0.13 | 0.25 |
| LPC1 | Lawns/Parks/Cemeteries (s<5) | 0.10 | 0.25 | 0.11 | 0.28 | 0.12 | 0.30 | 0.13 | 0.31 |
| LPC2 | Lawns/Parks/Cemeteries (s>5) | 0.25 | 0.40 | 0.28 | 0.44 | 0.30 | 0.48 | 0.31 | 0.50 |
| DL1 | Desert Landscaping 1 | 0.55 | 0.85 | 0.61 | 0.94 | 0.66 | 0.95 | 0.69 | 0.95 |
| DL2 | Desert Landscaping 2 | 0.30 | 0.40 | 0.33 | 0.44 | 0.36 | 0.48 | 0.38 | 0.50 |
| NDR | Undeveloped Desert Rangeland | 0.30 | 0.40 | 0.33 | 0.44 | 0.36 | 0.48 | 0.38 | 0.50 |
| NHS | Hillslopes, Sonoran Desert | 0.40 | 0.55 | 0.44 | 0.61 | 0.48 | 0.66 | 0.50 | 0.69 |
| NMT | Mountain Terrain | 0.55 | 0.80 | 0.61 | 0.88 | 0.66 | 0.95 | 0.69 | 0.95 |

Notes:

1. Runoff coefficients for 25-, 50- and 100-Year storm frequencies were derived using adjustment factors of 1.10, 1.20 and 1.25, respectively, applied to the 2-10 Year values with an upper limit of 0.95.
2. The ranges of runoff coefficients shown for urban land uses were derived from lot coverage standards specified in the zoning ordinances for Maricopa County.
3. Runoff coefficients for urban land uses are for lot coverage only and do not include the adjacent street and right-of-way, or alleys.
4. Values are based on the NDR terrain class. Values should be increased for NHS and NMT terrain classes by the difference between NHS (or NMT) and the NDR C values, up to a maximum of 0.95. Engineering judgement should be used.
5. Maricopa County has adopted specific values of C for each land use and storm frequency in the Drainage Policies and Standards for Maricopa County, Arizona (Maricopa County, 2007). These are the standard default values. The engineer/hydrologist may develop a computed composite value of C based on actual land uses, but must fully document the computations and assumptions and submit them to Maricopa County for approval. Many jurisdictions in Maricopa County may have adopted specific C coefficient values and procedures. The user should check with the appropriate agency before proceeding.

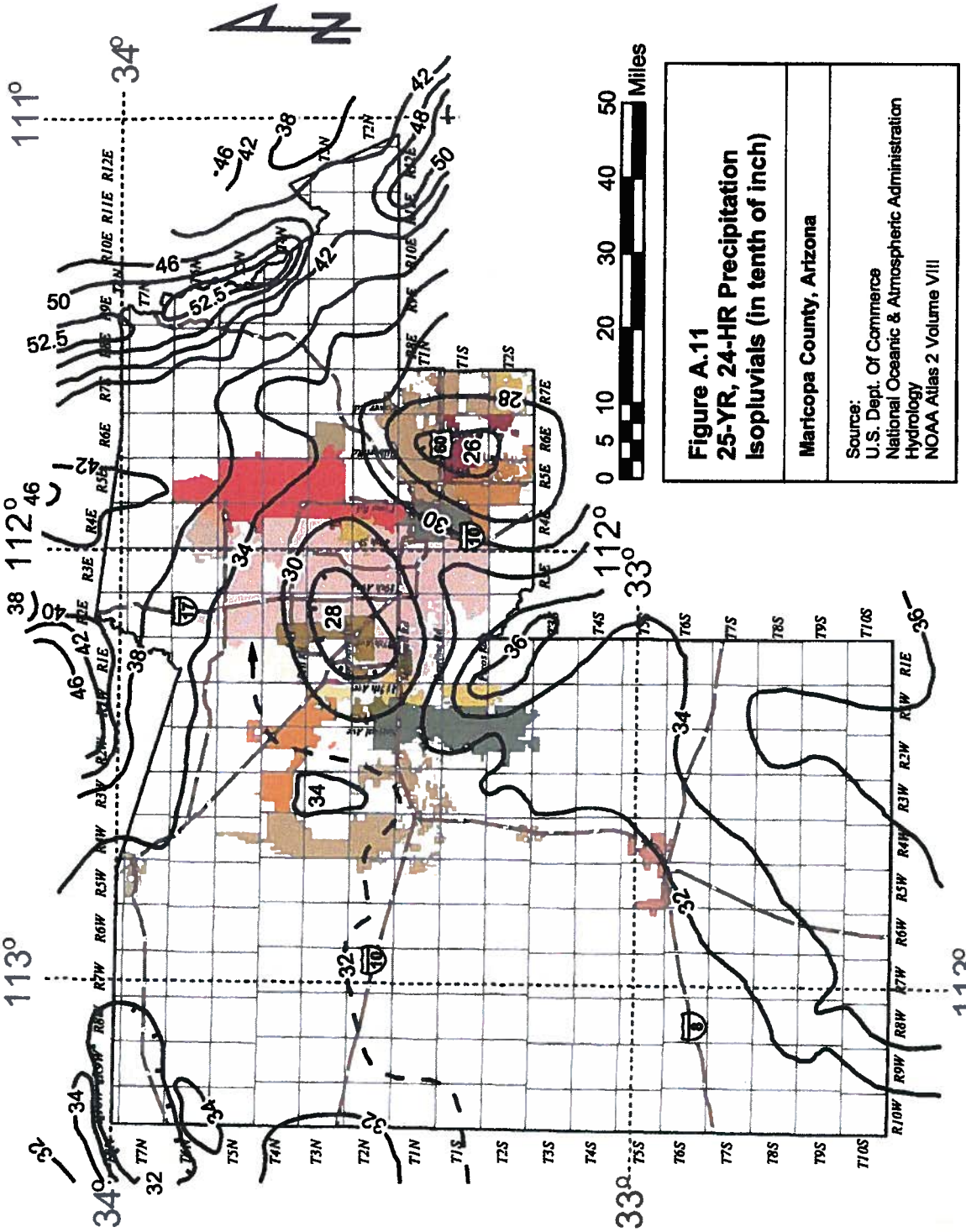


Figure A.11
25-YR, 24-HR Precipitation
Isopluvials (in tenth of inch)
Maricopa County, Arizona
Source:
U.S. Dept. Of Commerce
National Oceanic & Atmospheric Administration
Hydrology
NOAA Atlas 2 Volume VIII
0 5 10 20 30 40 50 Miles
111°
112°
113°
34°
33°