SPECIAL USE APPLICATION FOR APPEAL

NAME OF APPELLANT: Richard P. Noble

ADDRESS: 8375 Steel Bridge Road, Sheridan, Oregon

PHONE NUMBER: 503-437-0575

EMAIL ADDRESS: oregonwildlife@embarqmail.com;nancy.noble@gmail.com

NUMBER OF DOCKET APPEALED: SU-11 -13 .

DATE OF COMMISSION DECISION: January 11, 2012

DATE OF APPEAL SUBMITTAL: JAN 26 2012 FEE PAID: $ 300.

In addition to the $300 fee, the following information shall be provided before an appeal can be accepted. If more room is needed please attach additional pages.

1. Description of the decision being appealed. An appellant can appeal the Commission's decision for approval or disapproval or any conditions stipulated as part of docket approval.

   We appeal the decision approving a special use permit for Rainbow Solar Farm

2. A complete statement of all reasons why the appellant believes that the decision, or any part of the decision was erroneous, arbitrary, capricious, or any abuse of discretion.

See attachment.

3. Written presentation of additional testimony & evidence. A full explanation of the additional testimony & evidence that will be submitted with explanation of why this was not presented to the Planning Commission.

See attachment.

SIGNATURE [signature]

Attachment

2. **A complete statement of all reasons why the appellant believes that the decision, or any part of the decision was erroneous, arbitrary, capricious, or any abuse of discretion.**

The drainage plan for the solar installation diverts surface water away from stock tanks on the Riggs ranch and directs millions of gallons of water into a retention pond that drains directly into animal pens on my farm. These pens are used during the summer monsoon season for the birth of our animals and flooding will render them unusable.

Two commissioners voted to deny the special use permit. The three voting for approval agreed that the drainage problems must be corrected but accepted assurances from the developer and planning staff that the problems would be corrected in subsequent plans. We appeal this ruling because it grants total unreviewable and final authority to the developer and staff members on an issue vital to the continued use of our farms. If the decision is allowed to stand we will have no way to obtain a hearing on whatever future drainage plan they decide to implement. The ruling also prevents any further review by the planning commission or the board of supervisors.

In addition the commission gave inadequate consideration to the impact of the installation on property values of adjoining farms, dangers to aircraft using the adjoining airport at Cochise College from reflection and power poles, and impact on endangered wildlife in the area.

3. **Written presentation of additional testimony and evidence. A full explanation of the additional testimony and evidence that will be submitted with explanation of why this was not presented to the Planning Commission.**

Explanation:

With the use of slides and drawings I request an opportunity to present the following evidence.

a. Satellite photos from Google Earth showing the proposed solar farm, my farm and the RIggs ranch. This photo will show the natural flow of surface water from southwest to northeast. It will also show the location of the house and stock tanks on the Riggs property, and the animal pens and barns on my property.

b. The excavation and drainage plan contained in the application for a special use permit. This exhibit shows that the flow of water on the solar farm is to be diverted away from the Riggs property and into a retention pond that drains into my animal pens.

c. Precipitation records showing that rainfall in the area frequently exceeds two inches in a single day and 1 inch or more on multiple successive days. One inch of rainfall over a 320 acre farm equals 26.66 acre feet of water or 8,651,000 gallons. This exceeds the capacity of the proposed retention pond.

e. Photographs of my farm and Brooks road that show severe flooding when local rainfall exceeds 1 inch.

f. Published scientific reports that show peak water run off from solar farms is increased by as much as 100% above normal when the natural surface is replaced by gravel as planned for this installation. The studies also demonstrate that the kinetic energy of rainwater run off from solar panels is 10 times greater than natural rainfall. This excess force causes increased erosion of surface dirt which would be carried into the retention pond reducing its holding capacity.

g. Pictures of our animal holding pens and the animals that use the pens during the summer monsoon season.

This evidence was not presented to the planning commission because I was limited to five minutes in presenting my objections. This was not enough time to make a coherent explanation of our objections.

In addition a written statement of our opposition was not considered by most of the commission members. The notice of the proposed special use permit sent to us by the county planning department did not provide any suggestion that the solar farm developer planned to change the natural flow of surface water that reaches my farm. I first became aware of planned drainage changes when I was contacted by my neighbor Carol Riggs on Friday January 6. I worked as rapidly as possible to understand the proposed drainage plan and prepare objections. My letter of opposition was hand delivered to the planning department on January 11, the day of the hearing and five days after we learned of the proposed drainage plan. The letters were placed on the desks of the commissioners immediately prior to the commencement of the hearing. I believe only one commissioner had an opportunity to read it read it prior to approving the permit.

January 11, 2012

Richard P. Noble
8375 Steel Bridge Road
Sheridan, OR 97378

Community Development Department
Planning, Zoning and Building Safety
1415 Melody Lane
Bisbee, AZ 85603

Dear Commissioners:

I am the owner of the farm immediately south of the proposed site for the Rainbow Solar Facility. I strongly object to the excavation and drainage plan in the application for a special use permit. To the best of my knowledge the proposed plan was not included in the material sent to us by the county planning department. We first heard of the drainage plan late last week and have since acted as rapidly as possible to understand its consequences and prepare to present our concerns to the commission.

My farm and the proposed solar installation share a one half mile common boundary on the south side of my farm. The elevation of my farm is slightly lower than the solar farm property and when we have heavy rains or even moderate rains on successive days a great amount of water flows from the area of the proposed solar farm onto my property. We sustain a certain amount of flooding every summer. I am attaching photos showing the amount of water on the property during two successive rain storms in 2006. Much of the water shown in the photos flowed onto the property from the site of the proposed solar farm. The only way we avoid serious damage is that the slope of the land is very gentle and the water moves slowly over a broad area of the farm.

The excavation and drainage plan for the solar farm changes the topography and natural flow of water so that all of the water from the

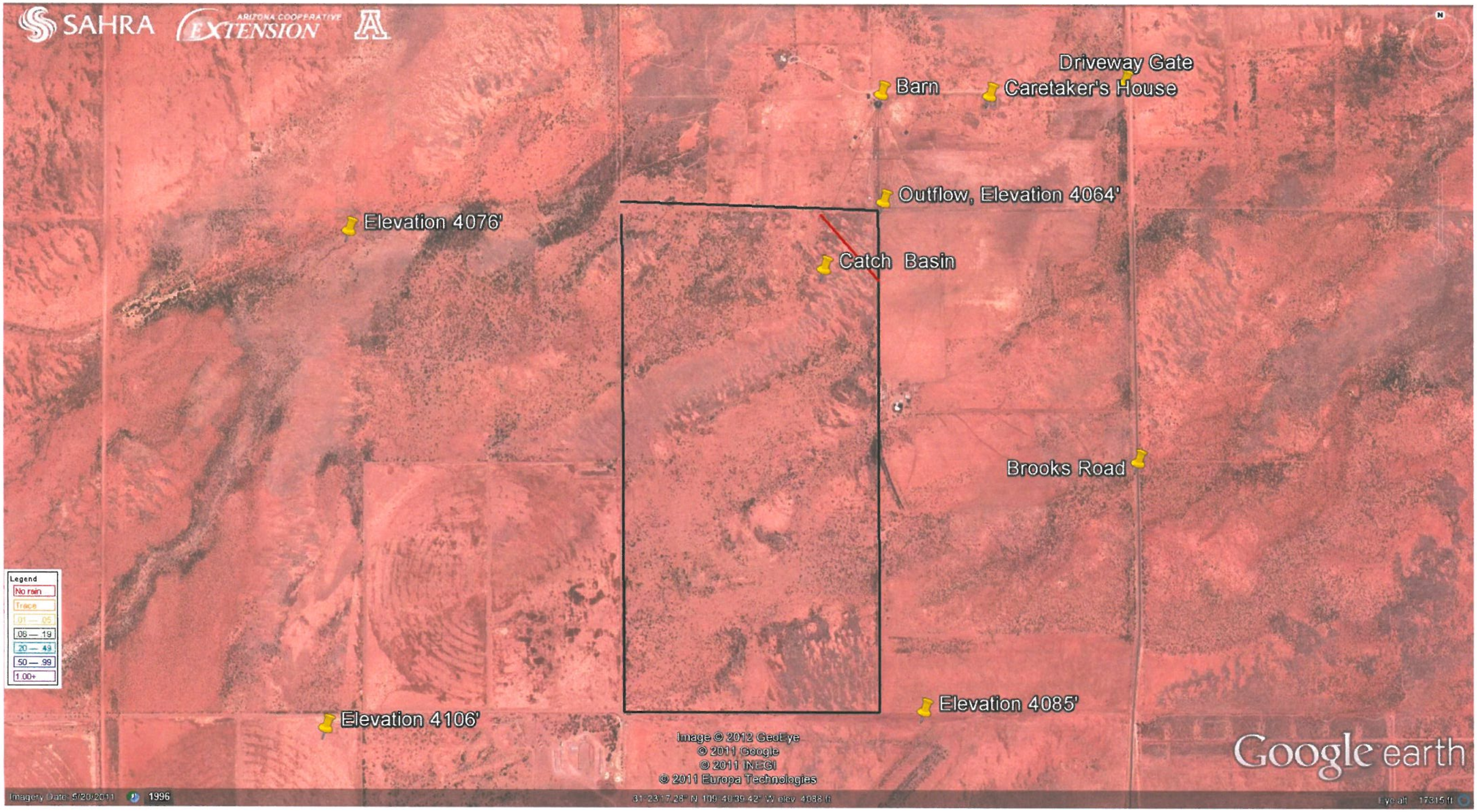
320 acres is directed to the south end of the property where it collects in a small retention pond and then drains onto my property and into small animal holding pens connected to our main barn. The excavation drawings submitted supporting the special use permit suggest that the retention area will hold 19.16 acre feet of water. I doubt the accuracy of this claim but even if it is accurate I believe this amount of water retention is totally inadequate. One acre inch of rain covering a 320 acre farm produces 26.66 acre feet of water. It is not at all uncommon to have more than an inch of rain in a few hours. Local precipitation records show instances when there has been as much as 2.5 inches in a single 24 hour period. When we have heavy rains in a single day or even moderate rains on successive days the retention pond will inevitably overflow and potentially millions of gallons of overflow water from the 320 acre solar farm will pass directly into my animal pens. For example, one inch of rain on a Monday would fill the pond. Another one inch on Tuesday would cause 26.66 acre feet of water (over 8.6 million gallons) to flow into my pens.

We raise endangered desert gazelle on our farm as part of a species survival program sponsored by the American Zoological Association. We use the pens around the barn during the summer months as a birthing area so we can monitor births and provide needed care for young calves during the first few months of their lives. The smaller calves weight approximately 3 pounds at birth and in my opinion would have little chance of survival if their pen were flooded. If this plan is allowed to be put in place it would be impossible for me to take the chance of using the main operational area of our program during the summer monsoon season.

I am including a number of pictures with this letter that I will seek to explain during the hearing.

Sincerely,

Dick Noble


SAHRA
ARIZONA COOPERATIVE EXTENSION
Driveway Gate
Barn
Caretaker's House
Outflow, Elevation 4064'
Elevation 4076'
Catch Basin
Brooks Road
Legend
No rain
Trace
.01 — .05
.06 — .19
.20 — .49
.50 — .99
1.00+
Elevation 4106'
Elevation 4085'
Image © 2012 GeoEye
© 2011 Google
© 2011 INEGI
© 2011 Europa Technologies
Google earth
Imagery Date: 5/20/2011
1996
31°23'17.28" N 109°40'39.42" W elev 4088 ft
Eye alt 17315 ft


SAHRA
ARIZONA COOPERATIVE EXTENSION
Barn
Caretaker's House
Driveway Gate
Brooks
Ultimate Outfall
Basin
Legend
No rain
Trace
.01 — .05
.06 — .19
.20 — .49
.50 — .99
1.00+
Image © 2012 GeoEye
© 2011 Google
© 2011 INEGI
Google earth
Imagery Date: 5/20/2011
1996
31°23'39.06" N 109°40'11.89" W elev 4063 ft
Eye alt 6217 ft
N

South fence line on property near site of proposed solar farm
probably taken July 29, 2006

Driveway at entrance to Brooks Road. The truck belongs to someone who worked on my barn construction on Saturday, July 29, 2006. Records from local weather station show rainfall on 7/28/06 of 1.09 inches, 7/29/06 of 1.03 inches, 7/30/06 of 1.41 inches.

Driveway gate at entrance to Brooks Road. Taken at time of second flood about 2 weeks after first flood. Records from local weather station show rainfall of .94 inches on August 11, 2006

One acre inch = 27,154 gallons

One acre foot = 325,851 gallons

One inch of rain water runoff from 320 acre solar farm = 26.66 acre feet of water. (320 divided by 12)

Rainbow solar farm claims a water retention capacity of only 19.16 acre feet.

Assuming one inch of rainfall per day for 3 successive days as we had in 2006.

Rainfall from day one would fill or possibly overflow retention capacity of solar farm.

With retention capacity full an additional one inch per day on days 2 and 3 would result in outflow of 53 acre feet (17,270,000 gallons) of water at the back of my animal pens.

An additional factor is that the retention basin will rapidly fill with surface dirt carried by the water running over bare ground and flowing into the basin.

SLENDER-HORNED GAZELLE

ORDER	FAMILY	GENUS & SPECIES
Artiodactyla	*Bovidae*	*Gazella leptoceros*

AMAZING FEATURES

- Enlarged, splayed hooves for walking on loose sand.
- Long, slender horns which earned this antelope its name are almost as long as the body.
- Large, dark eyes reflect Arabic meaning of "Ghazal" — bright-eyed.

WHERE IN THE WILD?

Dunes of the northern Sahara Desert of Africa and throughout northern Africa, including Algeria, Mali, Tunisia, Libya, Chad Sudan, Egypt, Mauritania & Morocco.


2010 3 3

February 27, 2012

Richard Noble
8375 Steel Bridge Rd
Sheridan, Oregon 97378

Dear Dick,

At your request, I'm sending my review of the site plan for the proposed solar facility. I'm out of the office at the moment so am sending this by email.

Review of proposed PV Field

The approval of a special use permit by the county must take into consideration the threats to public safety and private property that could occur as a result of granting of any new use. When you obtained a special use permit for your gazelle facility it was only considered after a licensed architect was engaged to provide stamped design drawings for the site and structures to be placed thereon. This petition for the solar farm must follow the same procedures.

In order to assure the proposed use does not adversely impact your farm, it is incumbent on the county to assure that all considerations have been addressed in the process of developing the property. I agree with your concerns that your farm will be flooded by the present design of the solar farm. To prevent this it is imperative that several conditions be placed on the special use permit as follows:

1. A licensed Arizona civil Engineer should be hired to provide engineering calculations and design specifications relating to the flow of water and retainment of water on the site in a manner that does not endanger the property, crops and lifestyle for the adjoining properties through a design process that addresses the following:

    a. 100 year rainfall intensity expected at the site. Rain falls of 1"total per storm, are common each year, and the known flooding that occurs from those rain events are always potentially destructive. The design of the solar farm site amenities appears to be inadequate to control the 24 hour quantity of water much less the possible high intensity level of such rain storms predicted by the 100 year rainfall intensity levels which may be as much as 4-5" per hour.

    b. Percolation tests for the particular property must be performed in order to predict the flow, absorption and "recovery" rate of the proposed retaining structure. Simply allowing excess water to exit the retaining structure onto adjoining property when its capacity is exceeded in an unacceptable design.

c. Sheet flow of water is being directed entirely to the northeast corner through construction of boundary roads, site grading and natural slopes. There are no structures being proposed to maintain the natural west to east flow, check the sheet flow or to deter the concentration of water in one place.

d. Drainage structures with steep slopes that are not stabilized with rip rap linings, gabions and or rock spillways will soon erode and collapse which will have the effect of inducing all sheet flow off site onto adjoining properties.

e. Plants and grasses will be destroyed by grading the site and the installation of the solar panels. There is no indication that soils will be stabilized via replanting of soil stabilizing vegetation.

The known problems with clay soils and flooding in this area of the country are clear, the unknowns of the proposed project and special use permit are how much will the project intensify the flooding and damage to property that will occur as a result of the drastic and purposeful changes to the fragile site conditions? However, casual calculations appear to show that the retaining pond is less than ½ of its required volume and the lack of other check dams and rock lined structures make the proposed design even more inadequate.

Sincerely;

Dale F Zinn Architect

NM # 960 , Inactive Arizona, Oregon, Maryland, Louisiana and Colorado
PO Box 756
Santa Fe, Nm 87504

Comments on Site Plan for "Rainbows Solar Energy"

Joel E. Geier, Ph.D.
38566 Hwy 99W
Corvallis, Oregon 97330

February 26, 2012

I am providing comments on this project as an acquaintance of the neighboring property owners, Dick and Nancy Noble. I have formal education and practical experience both in mining engineering (B.Sc. with honors, University of California, Berkeley, 1985) and hydrogeology (PhD in geology with emphasis in hydrogeology, Oregon State University, 2005). However, I am recommending, for a fully informed evaluation of this project, that the Nobles should seek the services of a professional hydrologist practicing in the State of Arizona. A complete evaluation by such an individual will likely require more time than is available between now and February 29, 2012.

Based on my examination of the project plans, I believe that the Nobles are justified in their concerns that this project will increase the risk of flooding on their property. The reasons for such concerns do not require specialized technical knowledge, and can be explained as follows:

1. The existing topographic contours, as shown on Sheets 2 & 3 of the plan, indicate that runoff during storm events will be toward the east in the southern half of the property to be developed (Sheet 3), and toward the northeast in the northern half of the property (Sheet 2). Thus runoff leaving the property, under current conditions, can flow both across the eastern boundary and across the northern boundary.
2. According to the drainage plan (Sheets 2 & 3), runoff in the southern half of the property will be directed due north, and runoff in the northern half will be directed either north or northeast toward a retention basin in the northeast corner, from whence the outflow is indicated to be across the northern boundary.
3. Thus rather than being distributed along the eastern and northern edges of the site, which have a combined length of 1.5 miles, runoff will be focused on the northern boundary which is just 0.5 miles in length - and likely focused further to a small fraction of that.
4. Without resort to complicated hydrologic models, a very simple estimate based on the relative linear length of these boundaries and inspection of topography is that about 1/3 of runoff from a precipitation event currently exits the site across its northern boundary, while the other 2/3 exits the site across the eastern boundary. After development, practically all of this runoff will be focused on the north boundary.
5. In addition to this focusing of runoff, the development is expected to cause

an increase in runoff per unit area of the site (due to factors such as removal of vegetation, installation of solar panels, and compaction of soils during construction and operation). This increase in runoff per unit area is acknowledged in the plans, in terms of an increased runoff coefficient (C value) in the "Retention Required Equation" (Sheet 2, lower left-hand corner). The runoff coefficient is estimated by the developer to increase from 0.41 pre-development, to 0.66 post-development.

6. The required volume of the retention pond has been calculated based on the increase in runoff proportional to the increase in the runoff coefficient. However, this calculation does not account for the focusing of runoff toward the northern boundary.
7. Using the same data as assumed by the developers' engineers in their plan, the total runoff from this site during a 100-yr, 1-hour precipitation event, in the pre-developed state, will be:

   0.41*(2.60 inches)*(320.79 ac)/(12 inches per foot) = 28.5 acre-feet

   of which roughly one third, or 9.5 acre-feet, currently exits via the north boundary per the simple assumption used in Point 4.
8. Again using the same data as assumed by the developers' engineers in their plan, the total runoff from this site, in its post-developed state, will be:

0.66*(2.60 inches)*(320.79 ac)/(12 inches per foot) = 45.9 acre-feet
practically all of which will be focused on the north boundary.

9. Thus these very simple calculations indicates that runoff directed toward the northern boundary, during a 100-yr, 1-hr storm event, could be increased by roughly:

   (45.9 acre-ft) - (9.5 acre-feet) = 36.4 acre-feet

This is nearly double the design capacity of the retention basin.

10. These calculations consider only the effects of a single, 100-year recurrence, 1-hour precipitation event. The pond has not been designed to hold excess runoff from multiple storm events that occur within a few days (such as occurred in late July, 2006), or storm events that last more than one hour on a single day. Weather data for the area show that single-day precipitation events of two inches or more are on record for most summer dates.
11. The capacity of the retention basin to prevent flooding on adjacent properties during a sequence of storm events will depend on the permeability of the underlying soil or sediments. Soil hydrologic properties have not been described or evaluated in the plans as presented.

Based on these observations and calculations, a more complete analysis of the potential for flooding across the north boundary should be conducted as a basis for design of mitigation measures. This should include:

1. An assessment of how runoff is currently routed by topography and the

resulting division of runoff between the two outflowing (northern and eastern) boundaries.

2. An assessment of how flow across the northern boundary will be increased by the proposed drainage plan.
3. An evaluation of the capacity of the retention basin to accommodate likely sequences of multi-hour and multi-day precipitation events, based on permeability data for soils or sediments of the type that are expected to form the bottom of the bottom.

These assessments will, in all probability, indicate that the development, as planned, has a foreseeable likelihood of causing increased flooding on adjoining property. Possible methods for mitigation include (1) redesign of the drainage pattern and eastern boundary road to maintain the existing pattern of distributed runoff, (2) enlargement of the proposed retention basin to give sufficient capacity, or (3) a combination of these measures.

Richard P. Noble
8375 Steel Bridge Road
Sheridan, OR 97378

February 28, 2012

Cochise County Board of Supervisors
County Complex, Building G
1415 Melody Lane
Bisbee, AZ 85603

Re: Docket SU-11-13 (Rainbow Solar Facility Appeal)

Dear Board of Supervisors:

I am enclosing the following material for consideration in support of my objection to the special use permit authorizing the construction of a solar facility on property adjacent to my farm.

1. Engineering report prepared by MultiTech Engineering Services concerning the drainage impact of the proposed Rainbow Solar Farm.

2. Report of Joel Greier Ph.D. Hydrologist.

3. Evaluation by Dale Zinn Architect who designed our farm and assisted us in obtain a special use permit to raise desert gazelles.

4. Our written presentation in opposition to the special use permit.

5. A group of documents supporting statements made in our presentation including precipitation and climate records, records of storm damage repair to Brooks Road and a Journal article titled "The Hydrological Response of Solar Farms" published in the Journal of Hydrological Engineering in October 2011.

Sincerely,

Richard Noble

Comments on Site Plan for "Rainbows Solar Energy"

Joel E. Geier, Ph.D.
38566 Hwy 99W
Corvallis, Oregon 97330

February 26, 2012

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February 27, 2012

Richard Noble
8375 Steel Bridge Rd
Sheridan, Oregon 97378

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The known problems with clay soils and flooding in this area of the country are clear, the unknowns of the proposed project and special use permit are how much will the project intensify the flooding and damage to property that will occur as a result of the drastic and purposeful changes to the fragile site conditions? However, casual calculations appear to show that the retaining pond is less than ½ of its required volume and the lack of other check dams and rock lined structures make the proposed design even more inadequate.

Sincerely;

Dale F Zinn Architect

NM # 960 , Inactive Arizona, Oregon, Maryland, Louisiana and Colorado
PO Box 756
Santa Fe, Nm 87504

Adjoining Land Owners' Presentation in Opposition to the Special Use Permit

Reasons for the Appeal

I own property adjacent to the proposed Rainbows End Solar Facility which shares a one half mile boundary on the south side of my farm. We raise endangered desert gazelles on the farm as part of a Species Survival Program of the American Zoological Association. We object to the solar facility because the present design of the drainage plan will cause serious flooding to critical parts of my farm. The plan calls for changing the surface grade which will divert the natural flow of water that is now west to east across the site, and direct it to the north and into a retention pond at my property line. The pond is not large enough to hold the run off from even a single heavy rain storm and the overflow will empty onto my property through a spillway and into birthing pens used by our pregnant gazelles. During periods of heavy rain the design could cause millions of gallons of water to pass through the overflow spillway and on to our farm.

Explanation for Additional Evidence

When I was notified by the planning commission of a proposed solar installation next to my farm I decided to accept the change in our neighborhood and not to file an objection to the proposal. There was nothing in the material sent to me that suggested the solar developer planned to change the natural flow of water crossing between our two properties. I first learned of a problem when my neighbor sent me a copy of her objection to the solar facility and mentioned that the facility would flood my gazelle pens. By that time the deadline to file objections to the plan had already passed. My wife and I quickly obtained a copy of the proposed drainage and excavation plan, recognized the problem and worked as rapidly as possible to prepare our objections to the proposal. Our written objections were hand delivered to the planning commission staff on the day of the hearing and were given to the commissioners in the hearing room a few minutes before the hearing began. I had prepared for a 30 minute presentation with drawings, precipitation records, run off calculations, photographs, and other material that I planned to present to the commissioners to explain our objections. However I was given only 5 minutes to state our objections and most of our material was not presented.

I believe the present drainage plan would not have been approved had I been able to adequately present our concerns first to the planning commission staff for consideration before the hearing and, if necessary, to the commission members at the hearing. Despite the limited presentation, two of the five member commission voted to reject the special use permit. The three members voting in favor of the permit expressed reservations about the drainage plan and acknowledged that it would need to be improved to address our concerns. One of the commissioners voting in favor actually suggested changes that could be considered. In the end however, three commissioners voted in favor of the permit on the basis that the planning commission and flood plain staff would require whatever changes were needed to keep my farm from being flooded. The reasons given were that granting the permit would allow the project to proceed and my problems could be dealt with along the way.

Objections to the Ruling Granting the Special Use Permit

Despite assurances from the commission that problems with the plan would be fixed along the way the result of the planning commission ruling is that the developer now has a permit containing an excavation and drainage plan that will cause serious and unnecessary damage to my farm. We believe that we must appeal this decision and ask that it be reversed.

The effect of the decision was to give prior approval to a plan that may be submitted in the future. At this time a new plan has not been presented or reviewed by anyone. If and when a new drainage plan is submitted it may be no better or even worse than the present plan. If that happens there is nothing we can do. The planning commission has already granted approval and we will have no forum where our complaints may be heard. The decision renders meaningless the statutory procedure giving adjoining landowners the right to object and have their objections heard and ruled upon by an impartial planning commission.

There was, and is, no need to rush this decision. At the hearing it was stated that the developer is applying for a commercial permit that will take approximately a year to process. Reversing the ruling of the commission will not stop or even delay the project as the developer can promptly submit a new plan.

Explanation for Our Objections

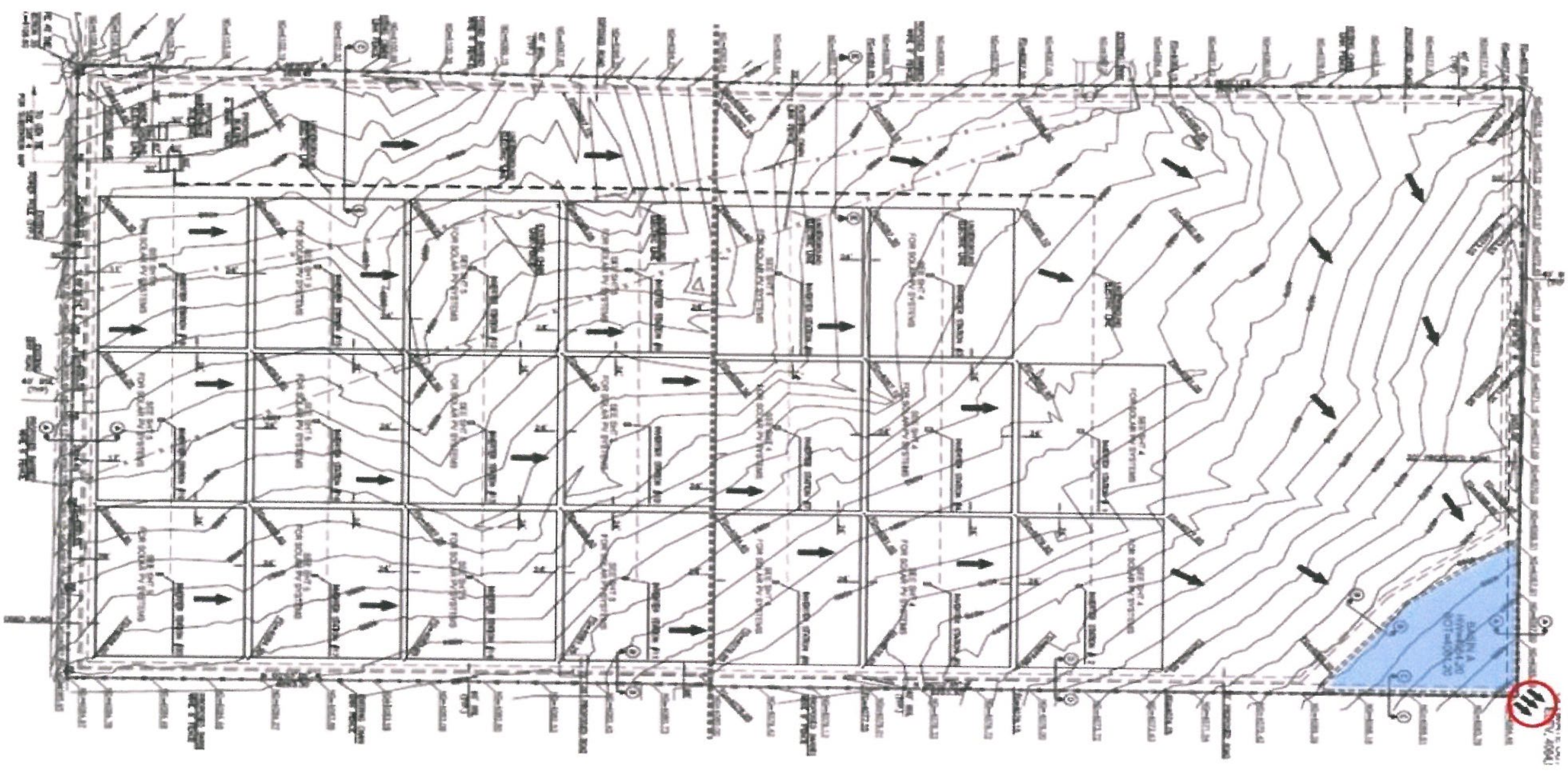
Currently, surface water crosses the solar site flowing from southwest to northeast. Water from the north end of the site drains onto my farm but much of the water from the south half of the site passes by us. The proposed drainage plan directs water from the entire 320 acre facility to an onsite retention pond which will overflow through a narrow spillway into animal pens on my farm.

The retention pond has a capacity of 19.16 acre feet of water whereas 1 inch of rain falling over 320 acres produces 27 acre feet. The pond will fill to capacity with the first monsoon rains. As the season progresses we can expect occasions when rainfall of two or more inches will fall within a few hours and it is not unusual to have an inch or more falling on multiple successive days. When the pond is full, run off from additional rain will rapidly pass through the pond and onto our property. A two inch downpour will produce 54 acre feet of run off spilling 17,595,954 gallons of water onto my farm. This overflow will be through a spillway concentrating the flow into a narrow torrent of water.

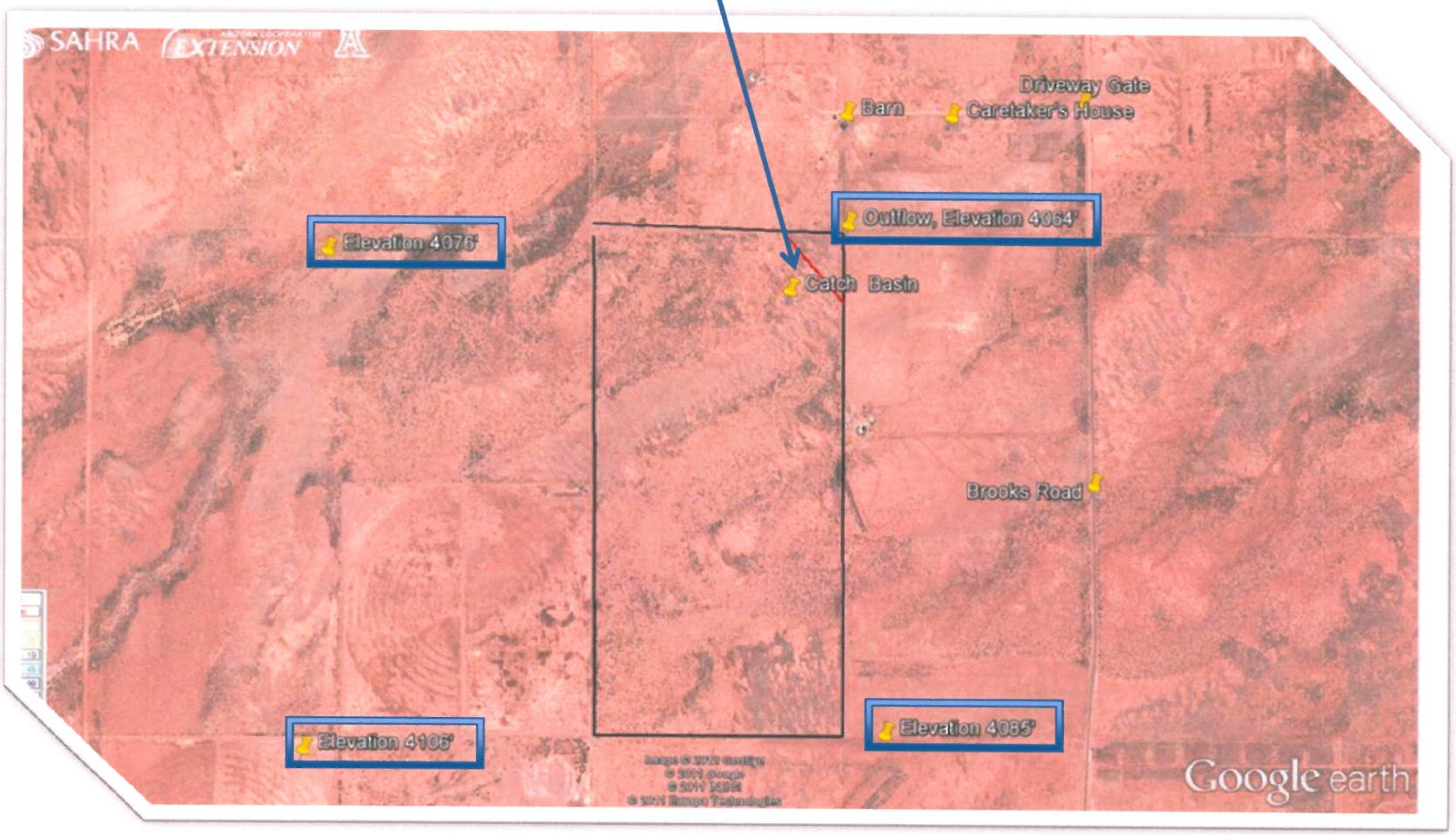
Finally the excavation plan calls for the removal of the natural grasses and brush, then grading the surface and covering it with gravel. This will turn the surface into something akin to a 320 acre parking lot greatly increasing the rate and amount of run off. Rainwater flowing off the sloped surface of the solar panels will strike the ground with a force calculated to be ten times the kinetic force of ordinary rainfall causing significant erosion. The eroded dirt will be carried to the retention pond gradually reducing its capacity and interfering with the infiltration of water into the soil at the bottom of the pond. Surfaces damaged by erosion will be difficult or impossible to repair in the presence of wall to wall solar panels covering the area. (This information is based on findings reported in the attached article *"The Hydrological Response of Solar Farms" published in the Journal of Hydrological Engineering, October 2011)*

The following copy of the drainage plan, photographs and other material are included to help explain our concerns and demonstrate the reasons we believe the permit should be denied.

The arrows designate the flow of water directing it into a retention pond at the extreme northeast corner. The retention pond capacity is 19.16 acre feet. Two inches of rain covering 320 acres produces 54 acre feet of water, nearly three times the capacity of the pond. Overflow from the pond passes through a spillway in the northeast corner of the pond and into animal pens on my farm.

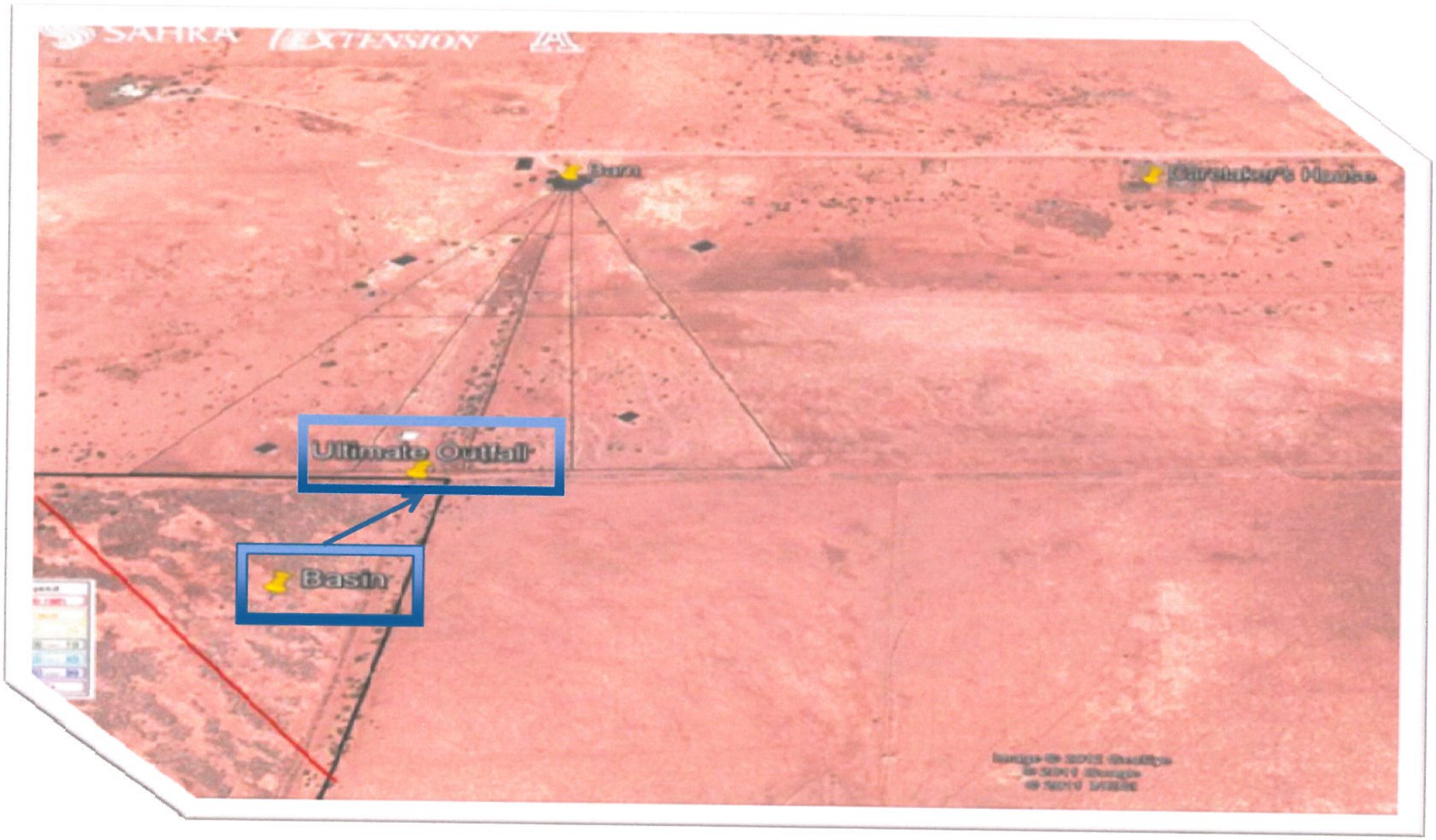


I have included the surface elevations at the four corners of the project. The natural flow is from the southwest to the northeast and corresponds with the pattern of vegetation markings running diagonally across the property. The proposed retention pond is marked in the northeast corner.



Google Earth Photo Of Proposed Solar Farm

This is a closer view of the north end of the solar farm and the adjoining animal pens on my farm. The point of outflow from the pond is directly in back of the pens. We keep pregnant gazelles in these pens during the summer to monitor births and look after the calves during their first weeks of life. Any substantial overflow from the pond will flood the pens making them too dangerous to use.



My Farm Already Sustains Serious Flooding From the Site of the Proposed Solar Site: This photograph was taken of my driveway on July 29, 2006. The gentleman who owned the truck had been working on my barn when we were hit by the second rainstorm in two days. As he attempted to leave he got stuck on my driveway. Much of the water flooding my property and crossing my driveway came from the site of the proposed solar farm. Fortunately, surface water reaching my farm from the solar site is spread over a wide area and moves slowly. The drainage plan would greatly increase the damage to my farm by capturing all of this water and releasing through a narrow spillway onto my farm.

Precipitation records around the time of this photo indicate:
1.09 inches on July 28,
1.03 inches on July 29
1.42 inches on July 30.

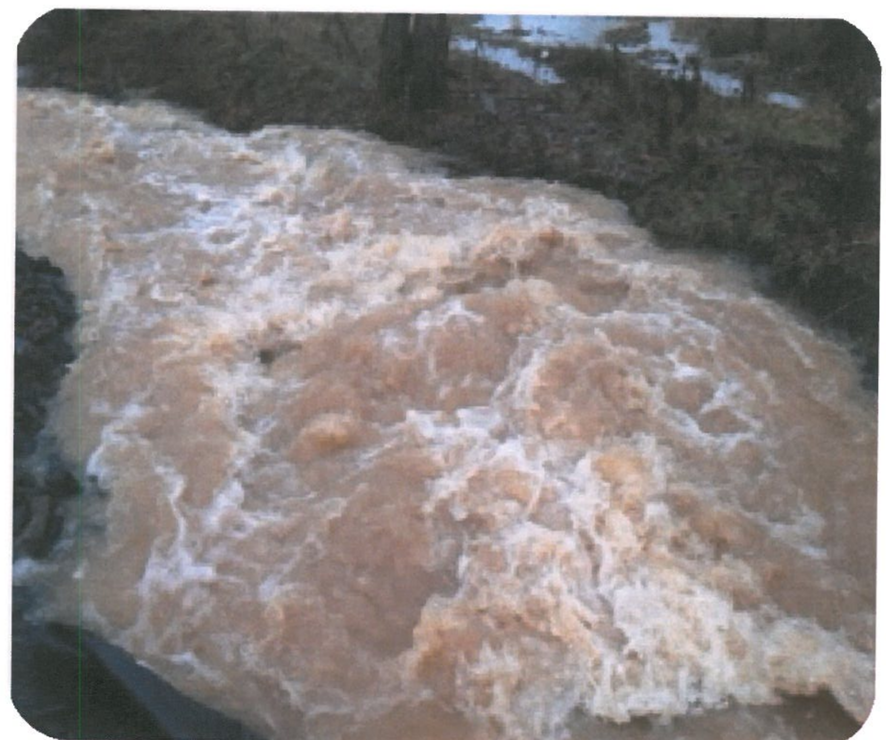
This photograph was also taken on July 29, 2006 along the south side of my farm about 1500 feet east of the proposed solar farm. Substantially all of the runoff in this photograph originated from the solar farm site. A recent article titled "The Hydrologic Response of Solar Farms" in the Journal of Hydrologic Engineering indicates that removal of the surface vegetation from a solar farm can increase the rate of runoff by as much as 100%. Any increase in the rate of runoff will cause substantial damage to my farm.

Storm Water Damage to Brooks Road from Water Running Off the Site of the Proposed Solar Farm

This photograph was taken at the end of my driveway where it enters Brooks Road. The picture was taken on August 11, 2006, 13 days after the flood shown in the earlier photos. It rained an additional 0.94 inches on August 11th.

Much of this water came from the site of the proposed solar farm. The records of the county road department relating to Brooks Road show that Cochise County spent over $11,000 repairing storm damage between 2006 and 2011. This damage will increase substantially if this amount of water is released in a small area and rushes rapidly onto Brooks Road.

These are photos of a pond and spillway on my farm in Oregon. The pond catches the run off from approximately 100 acres. It was raining hard on the day of the photo creating a torrent of water passing through the spillway. The retention pond on the solar facility will capture the run off from 320 acres passing it through a spillway such as this and onto my farm.



This is a recent photograph taken at the site of the proposed solar farm. The vegetation is typical of the entire 320 acre site. It is easy to understand how the vegetation naturally restricts the flow of surface water and why its removal will result in an increased volume of flow of storm water

Season Weather Averages

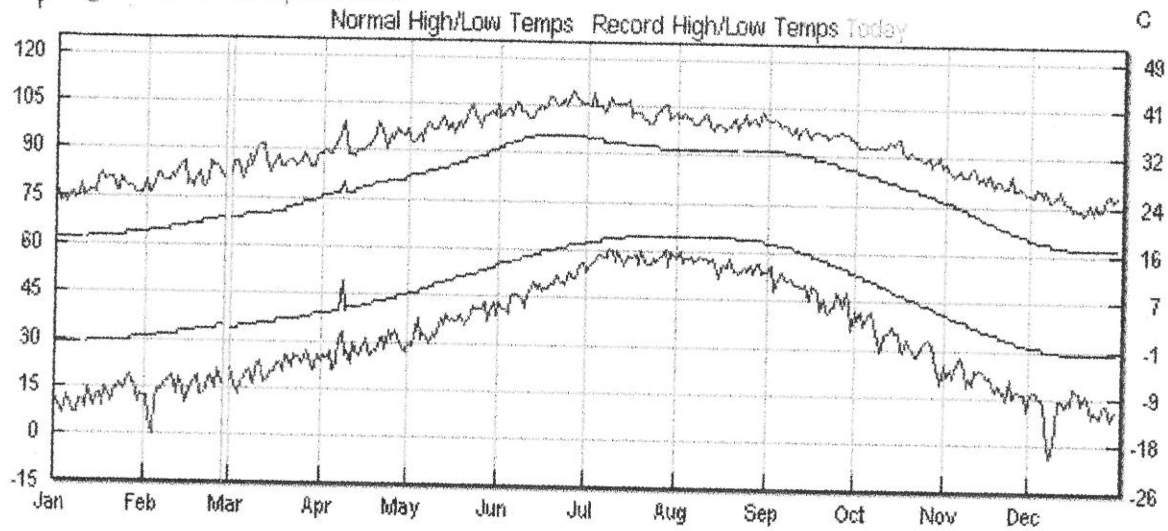
Bisbee Douglas International (KDUG)

Graphs of yearly temperature, rainfall, and snowfall.

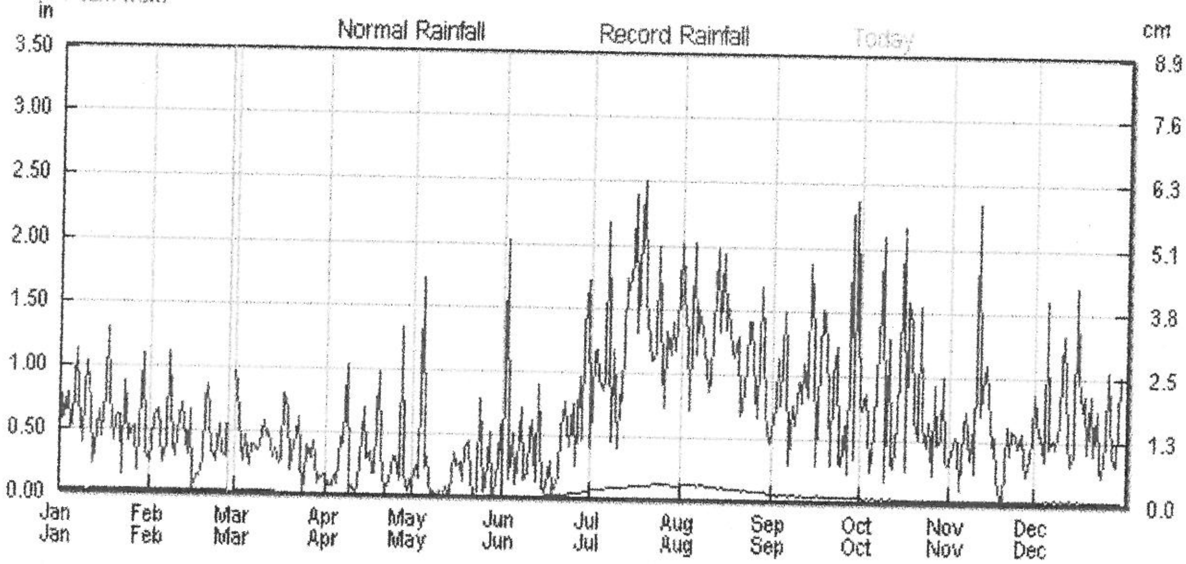
Current Conditions

- [ ] - Show Last Year
- [x] - Show Normals/Averages
- [x] - Show Records

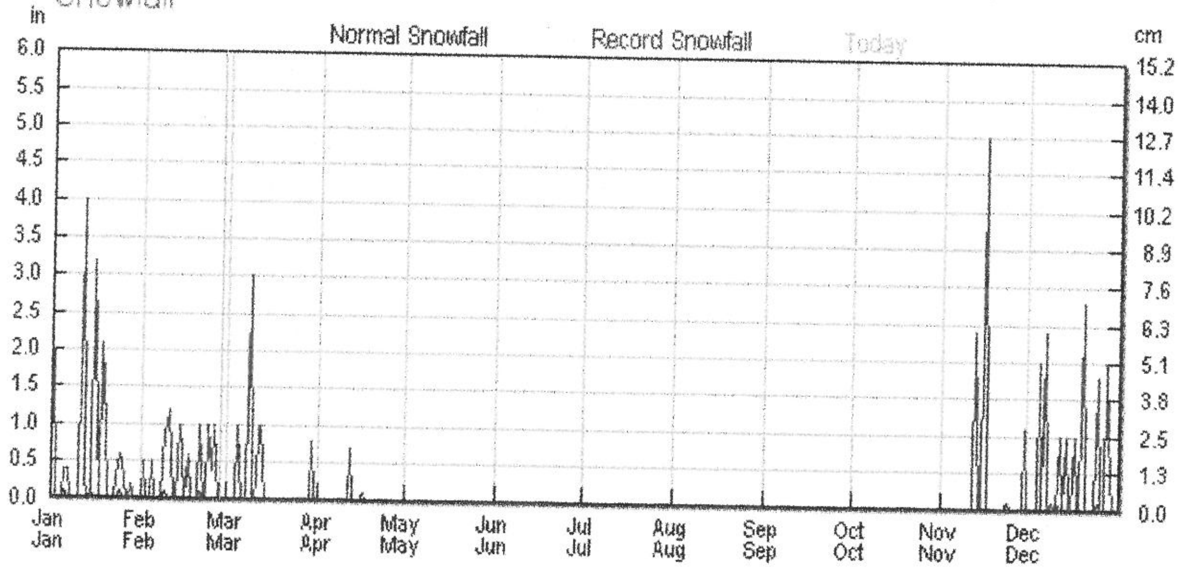
High / Low Temperature



Rainfall



Snowfall



From: "Salcido, Jennifer" <jsalcido@cochise.az.gov>
Subject: **Brooks Rd**
Date: January 30, 2012 10:02:03 AM PST
To: "oregonwildlife@embarqmail.com" <oregonwildlife@embarqmail.com>
3 Attachments, 413 KB

Mr. Noble,
Please find attached a report showing all work done on Brooks Road that is showing up in our database. If you are unable to open it, please let me know and I can send it in a different format.
If you have any further questions please do not hesitate to contact me. Thank you and have a wonderful day.

Jennifer Salcido
Administrative Aide - Operations
Cochise County Highway & Floodplain
1415 Melody Lane Bldg. F
Bisbee, AZ 85603
520-432-9355
jsalcido@cochise.az.gov

costtskdetbr....xls (406 KB)

Cochise County Highway and Floodplain Dept

Cost Detail Task/Location

Reporting Dates
Location E
Task A
Task Type A
Employee A
Contractor A
Fund A
Activity Note A

Task
0505 0505-ACIP-Sign Replacement/Removal

Act Date /ID		Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost
11/26/03	1,799	Brooks Rd	2.00	$27.32	$13.54	$112.69	$0.00	$0.00	$153.55
11/26/03	1,806	Brooks Rd	2.00	$26.96	$0.00	$0.00	$0.00	$0.00	$26.96
02/23/04	3,843	Brooks Rd	1.00	$13.48	$0.00	$0.00	$0.00	$0.00	$13.48
02/23/04	3,844	Brooks Rd	1.00	$13.66	$6.77	$0.00	$0.00	$0.00	$20.43
01/11/05	37,336	Brooks Rd	1.00	$10.62	$6.77	$37.72	$0.00	$0.00	$55.11
Brooks Rd Total			**7.00**	**$92.04**	**$27.08**	**$150.41**	**$0.00**	**$0.00**	**$269.53**
0505-ACIP-Sign Replacement/Removal Total			**7.00**	**$92.04**	**$27.08**	**$150.41**	**$0.00**	**$0.00**	**$269.53**

Task
102 102-Temporary Pavement Patch

Act Date /ID		Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost
02/02/04	1,971	Brooks Rd	3.00	$39.96	$9.28	$68.80	$0.00	$0.00	$118.04
05/02/05	44,861	Brooks Rd	2.00	$22.00	$6.37	$17.20	$0.00	$0.00	$45.57
05/02/05	44,862	Brooks Rd	2.00	$20.74	$0.00	$0.00	$0.00	$0.00	$20.74
08/01/06	82,810	Brooks Rd	10.00	$117.80	$72.00	$236.35	$0.00	$0.00	$426.15
08/01/06	82,811	Brooks Rd	10.00	$104.60	$15.50	$0.00	$0.00	$0.00	$120.10
08/01/06	82,812	Brooks Rd	10.00	$80.00	$0.00	$0.00	$0.00	$0.00	$80.00
08/02/06	82,832	Brooks Rd	9.00	$106.02	$126.00	$118.18	$0.00	$0.00	$350.20
08/02/06	82,833	Brooks Rd	9.00	$94.14	$15.50	$0.00	$0.00	$0.00	$109.64
08/02/06	82,834	Brooks Rd	9.00	$72.00	$0.00	$0.00	$0.00	$0.00	$72.00
07/11/07	111,595	Brooks Rd	9.00	$100.98	$72.50	$74.41	$0.00	$0.00	$247.89
07/11/07	111,596	Brooks Rd	9.00	$113.13	$0.00	$0.00	$0.00	$0.00	$113.13
07/16/08	174,433	Brooks Rd	5.00	$57.95	$157.40	$125.20	$0.00	$0.00	$340.55
07/16/08	174,434	Brooks Rd	5.00	$40.00	$0.00	$0.00	$0.00	$0.00	$40.00
09/25/08	194,641	Brooks Rd	2.00	$23.18	$8.10	$31.30	$0.00	$0.00	$62.58
09/25/08	194,642	Brooks Rd	2.00	$16.00	$0.00	$0.00	$0.00	$0.00	$16.00

421 421-Storm & Rock Patrol

Act Date /ID	Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost
08/07/06 83,931	Brooks Rd	1.00	$14.08	$7.50	$0.00	$0.00	$0.00	$21.58
Brooks Rd Total		**1.00**	**$14.08**	**$7.50**	**$0.00**	**$0.00**	**$0.00**	**$21.58**
421-Storm & Rock Patrol Total		**1.00**	**$14.08**	**$7.50**	**$0.00**	**$0.00**	**$0.00**	**$21.58**

Task

423 423-Storm Repair

Act Date /ID	Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost
07/27/06 82,999	Brooks Rd	7.00	$96.11	$96.00	$0.00	$0.00	$0.00	$192.11
07/27/06 83,000	Brooks Rd	7.00	$100.94	$148.50	$0.00	$0.00	$0.00	$249.44
07/27/06 83,001	Brooks Rd	7.00	$114.38	$198.00	$0.00	$0.00	$0.00	$312.38
07/27/06 83,002	Brooks Rd	7.00	$82.46	$96.00	$0.00	$0.00	$0.00	$178.46
07/27/06 83,003	Brooks Rd	7.00	$73.22	$16.00	$0.00	$0.00	$0.00	$89.22
08/01/06 83,315	Brooks Rd	10.00	$163.40	$271.50	$0.00	$0.00	$0.00	$434.90
08/01/06 83,316	Brooks Rd	6.00	$82.38	$96.00	$0.00	$0.00	$0.00	$178.38
08/01/06 83,317	Brooks Rd	10.00	$129.20	$288.00	$0.00	$0.00	$0.00	$417.20
08/01/06 83,318	Brooks Rd	6.00	$76.98	$128.00	$0.00	$0.00	$0.00	$204.98
09/06/06 86,520	Brooks Rd	7.00	$106.82	$92.00	$686.40	$0.00	$0.00	$885.22
09/06/06 86,521	Brooks Rd	10.00	$172.20	$184.00	$0.00	$0.00	$0.00	$356.20
09/06/06 86,522	Brooks Rd	10.00	$145.50	$186.00	$0.00	$0.00	$0.00	$331.50
09/06/06 86,523	Brooks Rd	10.00	$140.80	$184.00	$0.00	$0.00	$0.00	$324.80
09/07/06 86,712	Brooks Rd	10.00	$172.20	$145.50	$632.85	$0.00	$0.00	$950.55
09/07/06 86,713	Brooks Rd	10.00	$112.20	$138.00	$0.00	$0.00	$0.00	$250.20
09/07/06 86,714	Brooks Rd	10.00	$125.70	$91.00	$0.00	$0.00	$0.00	$216.70
09/07/06 86,715	Brooks Rd	8.00	$112.64	$213.00	$0.00	$0.00	$0.00	$325.64
09/07/06 86,716	Brooks Rd	9.00	$130.95	$79.25	$0.00	$0.00	$0.00	$210.20
11/13/06 92,688	Brooks Rd	7.00	$112.00	$138.00	$292.20	$0.00	$0.00	$542.20
11/13/06 92,689	Brooks Rd	7.00	$101.85	$69.00	$0.00	$0.00	$0.00	$170.85
11/13/06 92,690	Brooks Rd	7.00	$98.56	$69.00	$0.00	$0.00	$0.00	$167.56
11/14/06 92,709	Brooks Rd	10.00	$172.20	$191.50	$0.00	$0.00	$0.00	$363.70
11/14/06 92,710	Brooks Rd	10.00	$160.00	$161.00	$0.00	$0.00	$0.00	$321.00
11/14/06 92,711	Brooks Rd	10.00	$145.50	$163.00	$0.00	$0.00	$0.00	$308.50
11/15/06 92,725	Brooks Rd	9.00	$154.98	$145.50	$372.98	$0.00	$0.00	$673.46
11/15/06 92,726	Brooks Rd	9.00	$144.00	$163.00	$0.00	$0.00	$0.00	$307.00
11/15/06 92,727	Brooks Rd	9.00	$130.95	$92.00	$0.00	$0.00	$0.00	$222.95
11/15/06 92,728	Brooks Rd	8.00	$112.64	$92.00	$0.00	$0.00	$0.00	$204.64

07/20/10	278,246	Brooks Rd	5.00	$84.30	$168.00	$0.00	$0.00	$0.00	$252.30
08/06/10	278,392	Brooks Rd	10.00	$252.90	$318.30	$0.00	$0.00	$0.00	$571.20
08/07/10	278,397	Brooks Rd	5.00	$126.45	$168.00	$0.00	$0.00	$0.00	$294.45
08/09/10	409c	Brooks Rd	5.00	$84.30	$436.00	$51.74	$0.00	$0.00	$572.04
08/09/10	409c	Brooks Rd	4.00	$58.40	$0.00	$0.00	$0.00	$0.00	$58.40
08/09/10	409c	Brooks Rd	2.00	$23.26	$0.00	$0.00	$0.00	$0.00	$23.26
08/09/10	409c	Brooks Rd	4.00	$61.28	$0.00	$0.00	$0.00	$0.00	$61.28
08/09/10	409c	Brooks Rd	4.00	$54.24	$0.00	$0.00	$0.00	$0.00	$54.24
Brooks Rd Total			**276.00**	**$4,215.89**	**$5,025.05**	**$2,036.17**	**$0.00**	**$0.00**	**$11,277.11**

423-Storm Repair Total	**276.00**	**$4,215.89**	**$5,025.05**	**$2,036.17**	**$0.00**	**$0.00**	**$11,277.11**

Task

425 — 425-Emergency Storm Signing (call Out)

Act Date /ID		Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost
09/06/07	116,702	Brooks Rd	1.00	$14.29	$7.50	$0.00	$0.00	$0.00	$21.79
Brooks Rd Total			**1.00**	**$14.29**	**$7.50**	**$0.00**	**$0.00**	**$0.00**	**$21.79**

425-Emergency Storm Signing (call Out) Tot:	**1.00**	**$14.29**	**$7.50**	**$0.00**	**$0.00**	**$0.00**	**$21.79**

Task

499 — 499-Other Drainage Maintenance

Act Date /ID		Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost
07/05/06	80,700	Brooks Rd	2.00	$25.84	$15.00	$0.00	$0.00	$0.00	$40.84
07/05/06	80,701	Brooks Rd	2.00	$16.00	$0.00	$0.00	$0.00	$0.00	$16.00
07/10/06	81,330	Brooks Rd	1.00	$12.92	$7.50	$0.00	$0.00	$0.00	$20.42
07/17/06	81,626	Brooks Rd	1.00	$12.92	$7.50	$0.00	$0.00	$0.00	$20.42
07/19/06	81,650	Brooks Rd	1.00	$12.92	$7.50	$0.00	$0.00	$0.00	$20.42
07/09/07	111,789	Brooks Rd	1.00	$14.08	$7.50	$0.00	$0.00	$0.00	$21.58
Brooks Rd Total			**8.00**	**$94.68**	**$45.00**	**$0.00**	**$0.00**	**$0.00**	**$139.68**

499-Other Drainage Maintenance Total	**8.00**	**$94.68**	**$45.00**	**$0.00**	**$0.00**	**$0.00**	**$139.68**

Task

500 — 500-Sign Inspection Nighttime

Act Date /ID	Location	Labor Hours	Labor Cost	Eqp Cost	Mat Cost	Con Cost	Overhead	Total Cost

Journal of Hydrologic Engineering. Submitted August 12, 2010; accepted October 20, 2011;
posted ahead of print October 24, 2011. doi:10.1061/(ASCE)HE.1943-5584.0000530

THE HYDROLOGIC RESPONSE OF SOLAR FARMS

Lauren M. Cook[1] and Richard H. McCuen[2]

ABSTRACT

Because of the benefits of solar energy, the number of solar farms is increasing; however, their hydrologic impacts have not been studied. The goal here was to determine the hydrologic effects of solar farms and examine whether or not stormwater management is needed to control runoff volumes and rates. A model of a solar farm was used to simulate runoff for two conditions: the pre- and post-paneled conditions. Using sensitivity analyses, modeling showed that the solar panels themselves did not have a significant effect on the runoff volumes, peaks, or times to peak. However, if the ground cover under the panels is gravel or bare ground, due to design decisions or lack of maintenance, the peak discharge may increase significantly, with stormwater management needed. In addition, the kinetic energy of the flow that drains from the panels was found to be greater than that of the rainfall, which could cause erosion at the base of the panels. Thus, it is recommended that the grass beneath the panels be well maintained or that a buffer strip be placed after the most down gradient row of panels. This study, along with design recommendations, can be used as a guide for the future design of solar farms.

KEYWORDS: Hydrology; land use change; solar energy; flooding; surface water runoff; stormwater management

INTRODUCTION

Stormwater management practices are generally implemented to reverse the effects of land cover changes that cause increases in volumes and rates of runoff. This is a concern posed for new types of land cover change such as the solar farm. Solar energy is a renewable energy

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source that is expected to increase in importance in the near future. As solar farms require considerable land, it is necessary to understand the design of solar farms and their potential effect on erosion rates and storm runoff, especially the impact on offsite properties and receiving streams. These farms can vary in size from 8 ha (20 acres) in residential areas to 250 ha (600 acres) in areas where land is abundant.

The solar panels are impervious to rain water; however, they are mounted on metal rods and placed over pervious land. In some cases, the area below the panel is paved or covered with gravel. Service roads are generally located between rows of panels. While some panels are stationary, others are designed to move so that the angle of the panel varies with the angle of the sun. The angle can range, depending on the latitude, from 22° during the summer months to 74° during the winter months. In addition, the angle and direction can also change throughout the the day. The issue posed is whether or not these rows of impervious panels will change the runoff characteristics of the site, specifically increase runoff volumes or peak discharge rates. If the increases are hydrologically significant, stormwater management facilities may be needed. Additionally, it is possible that the velocity of water draining from the edge of the panels is sufficient to cause erosion of the soil below the panels, especially where the maintenance roadways are bare ground.

The outcome of this study provides guidance for assessing the hydrologic effects of solar farms, which is important to those who plan, design, and install arrays of solar panels. Those who design solar farms may need to provide for stormwater management. This study investigated the hydrologic effects of solar farms, assessed whether or not stormwater management might be needed, and if the velocity of the runoff from the panels could be sufficient to cause erosion of the soil below the panels.

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MODEL DEVELOPMENT

Solar farms are generally designed to maximize the amount of energy produced per unit of land area, while still allowing space for maintenance. The hydrologic response of solar farms is not usually considered in design. Typically, the panels will be arrayed in long rows with separations between the rows to allow for maintenance vehicles. To model a typical layout, a unit width of one panel was assumed, with the length of the down gradient strip depending on the size of the farm. For example, a solar farm with 30 rows of 200 panels each could be modeled as a strip of 30 panels with space between the panels for maintenance vehicles. Rainwater that drains from the upper panel onto the ground will flow over the land under the 29 panels on the down gradient strip. Depending on the land cover, infiltration losses would be expected as the runoff flows to the bottom of the slope.

To determine the effects that the solar panels have on runoff characteristics, a model of a solar farm was developed. Runoff in the form of sheet flow without the addition of the solar panels served as the pre-paneled condition. The paneled condition assumed a downgradient series of cells, with one solar panel per ground cell. Each cell was separated into three sections: wet, dry, and spacer.

The dry section is that portion directly underneath the solar panel, unexposed directly to the rainfall. As the angle of the panel from the horizontal increases, more of the rain will fall directly onto the ground; this section of the cell is referred to as the wet section. The spacer section is the area between the rows of panels used by maintenance vehicles. Figure 1 is an image of two solar panels and the spacer section allotted for maintenance vehicles. Figure 2 is a schematic of the wet, dry, and spacer sections with their respective dimensions. In Figure 1, tracks from the vehicles are visible on what is modeled within as the spacer section. When the

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solar panel is horizontal, then the length longitudinal to the direction that runoff will occur is the length of the dry and wet sections combined. Runoff from a dry section drains onto the downgradient spacer section. Runoff from the spacer section flows to the wet section of the next downgradient cell. Water that drains from a solar panel falls directly onto the spacer section of that cell.

The length of the spacer section is constant. During a storm event, the loss rate was assumed constant for the 24-hour storm, as a wet antecedent condition was assumed. The lengths of the wet and dry sections changed depending on the angle of the solar panel. The total length of the wet and dry sections was set equal to the length of one horizontal solar panel, which was assumed to be 3.5 meters. When a solar panel is horizontal, the dry section length would equal 3.5 m, and the wet section length would be zero. In the paneled condition, the dry section does not receive direct rainfall, as the rain first falls onto the solar panel, then drains onto the spacer section. However, the dry section does infiltrate some of the runoff that comes from the upgradient wet section. The wet section was modeled similar to the spacer section, with rain falling directly onto the section and assuming a constant loss rate.

For the pre-solar panel condition, the spacer and wet sections are modeled the same as in the paneled condition; however, the cell does not include a dry section. In the pre-paneled condition, rain falls directly onto the entire cell. When modeling the pre-paneled condition, all cells receive rainfall at the same rate and are subject to losses. All other conditions were assumed to remain the same such that the pre-paneled and paneled conditions can be compared.

Rainfall was modeled after an NRCS Type II Storm (McCuen 2005) because it is an accurate representation of actual storms of varying characteristics that are imbedded in intensity-duration-frequency (IDF) curves. For each duration of interest, a dimensionless hyetograph was

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developed using a time increment of 12 seconds over the duration of the storm (see Figure 3). The depth of rainfall that corresponds to each storm magnitude was then multiplied the dimensionless hyetograph. For a 2-hr storm duration, depths of 40.6, 76.2, and 101.6 mm were used for the 2-yr, 25-yr, and 100-yr events. The 2-hr and 6-hr duration hyetographs were developed using the center portion of the 24-hr storm, with the rainfall depths established with the Baltimore IDF curve. The corresponding depths for a 6-hr duration were 53.3, 106.7, and 132.1 mm, respectively. These magnitudes were chosen to give a range of storm conditions.

During each time increment, the depth of rain is multiplied by the cell area to determine the volume of rain added to each section of each cell. This volume becomes the storage in each cell. Depending on the soil group, a constant volume of losses was subtracted from the storage. The runoff velocity from a solar panel was calculated using Manning's equation, with the hydraulic radius for sheet flow assumed to equal the depth of the storage on the panel (Bedient and Huber, 2002). Similar assumptions were made to compute the velocities in each section of the surface sections.

Runoff from one section to the next and then to the next downgradient cell was routed using the continuity of mass. The routing coefficient depended on the depth of flow in storage and the velocity of runoff. Flow was routed from the wet section to the dry section to the spacer section, with flow from the spacer section draining to the wet section of the next cell. Flow from the most downgradient cell was assumed to be the outflow. Discharge rates and volumes from the most downgradient cell were used for comparisons between the pre-paneled and paneled conditions.

ALTERNATIVE MODEL SCENARIOS

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To assess the effects of the different variables, a section of thirty cells, each with a solar panel, was assumed for the base model. Each cell was separated individually into wet, dry, and spacer sections. The area had a total ground length of 225 meters with a ground slope of 1% and width of 5 meters, which was the width of an average solar panel. The roughness coefficient (Engman 1986) for the silicon solar panel was assumed to be that of glass, 0.01. Roughness coefficients of 0.15 for grass and 0.02 for bare ground were also assumed. Loss rates of 0.5715 cm/hr (0.225 in./hr) and 0.254 cm/hr (0.1 in./hr) for B and C soils, respectively, were assumed.

The pre-paneled condition using the 2-hr, 25-yr rainfall was assumed for the base condition, with each cell assumed to have a good grass cover condition. All other analyses were made assuming a paneled condition. For most scenarios the runoff volumes and peak discharge rates from the paneled model were not significantly greater than those for the pre-paneled condition. Over a total length of 225 meters with 30 solar panels, the runoff increased by 0.26 m^3, which was a difference of only 0.35 %. The slight increase in runoff volume reflects the slightly higher velocities for the paneled condition. The peak discharge increased by 0.0013 m^3, a change of only 0.31 %. The time to peak was delayed by one time increment, i.e., 12 seconds. Inclusion of the panels did not have a significant hydrologic impact.

Storm Magnitude

The effect of storm magnitude was investigated by changing the magnitude from a 25-year storm to 2-year storm. For the 2-year storm, the rainfall and runoff volumes decreased by about 50 %. However, the runoff from the paneled watershed condition increased compared to the pre-paneled condition by approximately the same volume as for the 25-yr analysis, 0.26 m^3. This increase represents only a 0.78 % increase in volume. The peak discharge and the time to

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peak did not change significantly. These results reflect runoff from a good grass cover condition, and indicated that the general conclusion of very minimal impacts was the same for different storm magnitudes.

Ground Slope

The effect of the downgradient ground slope of the solar farm was also examined. The angle of the solar panels would influence the velocity of flows from the panels. As the ground slope was increased, the velocity of flow over the ground surface would be closer to that on the panels. This could cause an overall increase in discharge rates. The ground slope was changed from 1 % to 5 %, with all other conditions remaining the same as the base conditions.

With the steeper incline, the volume of losses decreased from that for the 1% slope, which is to be expected, as the faster velocity of the runoff would provide less opportunity for infiltration. However, between the pre-paneled and paneled conditions, the increase in runoff volume was less than 1%. The peak discharge and the time to peak did not change. Therefore, the greater ground slope did not significantly influence the response of the solar farm.

Soil Type

The effect of soil type on the runoff was also examined. The soil group was changed from B soil to C soil by varying the loss rate. As expected, due to the higher loss rate for the C soil, the depths of runoff increased by about 7.5% with the C soil when compared with the volume for B soils. However, the runoff volume for the C soil condition only increased by 0.17 % from the pre-paneled condition to the paneled condition. In comparison with the B soil, a difference of 0.35 % in volume resulted between the two conditions. Therefore, the soil group ground. Due to the higher velocities of the flow, runoff rates from the cells increased significantly such that it was necessary to reduce the computational time increment. Figure 4 shows the hydrograph from a 30-panel area with a time increment of 12 seconds. With a time increment of 12 seconds, the water in each cell is discharged at the end of every time increment, which results in no attenuation of the flow; thus, the undulations shown in Figure 4 result. The time increment was reduced to 3 seconds for the 2-hour storm, which resulted in watershed smoothing and a rational hydrograph shape. The results showed that the storm runoff increased by 7% from the grass covered scenario to the scenario with gravel under the panel. The peak discharge increased by 73% for the gravel ground cover when compared to the grass cover without the panels. The time to peak was 10 minutes less with the gravel than with the grass, which reflects the effect of differences in surface roughness and the resulting velocities.

If maintenance vehicles used the spacer section regularly and the grass cover was not adequately maintained, the soil in the spacer section would be compacted and potentially the runoff volumes and rates would increase. It is possible that, if the grass is not maintained, then it could become patchy and turn to bare ground. The grass under the panel may not get enough sunlight and die. Figure 1 shows the result of the maintenance trucks frequently driving in the spacer section, which diminished the grass cover.

The effect of the lack of solar farm maintenance on runoff characteristics was modeled by changing the Manning's n to a value of 0.02 for bare ground. In this scenario, the roughness coefficient for the ground under the panels, i.e., the dry section, as well as in the spacer cell was changed from grass covered to bare ground (n = 0.02).The effects were nearly identical to that of the gravel. The runoff volume increased by 7% from the grass covered condition to the bare ground condition. The peak discharge increased by 72% when compared with the grass covered condition. The runoff for the bare ground condition also resulted in an earlier time to peak by about 10 minutes. Two other conditions were also modeled, showing similar results. In the first scenario, gravel was placed directly under the panel, and healthy grass was placed in the spacer section, which mimics a possible design decision. Under these conditions, the peak discharge increased by 42%, and the volume of runoff increased by 4%, which suggests that, if gravel is placed anywhere, stormwater management would be necessary.

Figure 5 shows two solar panels from a solar farm in New Jersey. The bare ground between the panels can cause increased runoff rates and reductions in time of concentration, both of which could necessitate stormwater management. The final condition modeled involved the assumption of healthy grass beneath the panels and bare ground in the spacer section, which would simulate the condition of unmaintained grass due to vehicles that drive over the spacer section. Since the spacer section is 53% of the cell, then the change in land cover to bare ground would reduce losses and decrease runoff travel times, which would cause runoff to amass as it moves downgradient. With the spacer section as bare ground, the peak discharge increased by 100%, which reflected the increases in volume and decrease in timing. These results illustrate the need for maintenance of the grass below and between the panels.

DESIGN SUGGESTIONS

With well maintained grass underneath the panels, the solar panels themselves do not have much effect on total volumes of the runoff or peak discharge rates. While the panels are impervious, the rainwater that drains from the panels appears as runoff over the downgradient cells. Some of the runoff infiltrates. If the grass cover of a solar farm is not maintained, it can deteriorate due to either a lack of sunlight or maintenance vehicle traffic. In this case, the runoff

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characteristics can change significantly with both runoff rates and volumes increasing by significant amounts. In addition, if gravel or pavement is placed underneath the panels, this can also contribute to a significant increase in the hydrologic response.

If bare ground is foreseen to be a problem or gravel is to be placed under the panels to prevent erosion, it is necessary to counteract the excess runoff using some form of stormwater management. A simple practice that can be implemented is a buffer strip (Dabney et al., 2006) at the downgradient end of the solar farm. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the gravel and panels were installed. Alternatively, a detention basin can be installed.

A buffer strip was modeled along with the panels. For roughly every 200 meters of panels, or 29 cells, the buffer must be 5 cells long, or 35 meters, to reduce the runoff volume to that which occurred before the panels were added. Even if a gravel base is not placed under the panels, the inclusion of a buffer strip may be a good practice when grass maintenance is not a top funding priority. Figure 6 shows the peak discharge from the graveled surface versus the length of the buffer needed to keep the discharge to pre-paneled peak rate.

Water draining from a solar panel can increase the potential for erosion of the spacer section. If the spacer section is bare ground, the high kinetic energy of water draining from the panel can cause soil detachment and transport (Garde and Raju, 1977; Beuselinck et al. 2002). The amount and risk of erosion was modeled using the velocity of water coming off of a solar panel compared to the velocity and intensity of the rainwater. The velocity of panel runoff was calculated using Manning's equation, and the velocity of falling rainwater was calculated using the equation:

$$V_t = 120\ d_r^{0.35} \tag{1}$$

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with d_r is the diameter of a raindrop, assumed to be 1 mm. The relation between kinetic energy and rainfall intensity is:

$$K_e = 916 + 330 \log_{10} i \tag{2}$$

where i is the rainfall intensity (in./hr) and K_e is the kinetic energy (ft-tons per ac-in. of rain) of rain falling onto the wet section and the panel, as well as the water flowing off of the end of the panel (Wischmeier and Smith 1978). The kinetic energy (Salles et al. 2002) of the rainfall was greater than that coming off of the panel, but, the area under the panel, i.e., the product of the length, width, and cosine of the panel angle, is greater than the area under the edge of the panel where the water drains from the panel onto the ground. Thus, dividing the kinetic energy by the respective areas, gives a more accurate representation of the kinetic energy experienced by the soil. The energy of the water draining from the panel onto the ground can be nearly 10 times more than the rain itself falling onto the ground area. If the solar panel runoff falls onto an unsealed soil, considerable detachment can result (Motha 2004). Thus, due to the increased kinetic energy, it is possible that the soil is much more prone to erosion with the panels than without. Where panels are installed, methods of erosion control should be included in the design.

CONCLUSIONS

Solar farms are the energy generators of the future, and thus it is important to determine the environmental and hydrologic effects of these farms, both existing and proposed. A model was created to simulate stormwater runoff over a land surface without panels and then with solar panels added. Various sensitivity analyses were conducted including changing the storm duration and volume, soil type, ground slope, panel angle, and ground cover to determine the effect that each of these factors would have on the volumes and peak discharge rates of the runoff.

The addition of solar panels over a grassy field does not have much of an effect on the volume of runoff, the peak discharge, nor the time to peak. With each analysis, the runoff volume increased slightly, but not enough to require stormwater management facilities. However, when the land cover type was changed under the panels, the hydrologic response changed significantly. When gravel or pavement was placed under the panels, with the spacer section left as patchy grass or bare ground, the volume of the runoff increased significantly and the peak discharge increased by about 100%. This was also the result when the entire cell was assumed to be bare ground.

The potential for erosion of the soil at the base of the solar panels was also studied. It was determined that the kinetic energy of the water draining from the solar panel could be as much as 10 times greater than that of rainfall. Thus, since the energy of the water draining from the panels is much higher, it is very possible that soil below the base of the solar panel could erode due to the concentrated flow of water off of the panel, especially if there is bare ground in the spacer section of the cell. If necessary, erosion control methods should be used.

Bare ground beneath the panels and in the spacer section is a realistic possibility (see Figures 1 and 5). Thus, a good, well maintained grass cover beneath the panels and in the spacer section is highly recommended. If gravel, pavement, or bare ground is deemed unavoidable below the panels or in the spacer section, it may necessary to add a buffer section to control the excess runoff volume and ensure adequate losses. If these simple measures are taken, solar farms will not have an adverse hydrologic impact from excess runoff or contribute eroded soil particles to receiving streams and waterways.

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The authors appreciate the photographs (Figures 1 and 5) of Ortho Clinical Diagnostics, 1001 Route 202, North Raritan, New Jersey, 08869, provided by John E. Showler, Environmental Scientist, NJ Department of Agriculture. The extensive comments of reviewers resulted in an improved paper.

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F.gure 1

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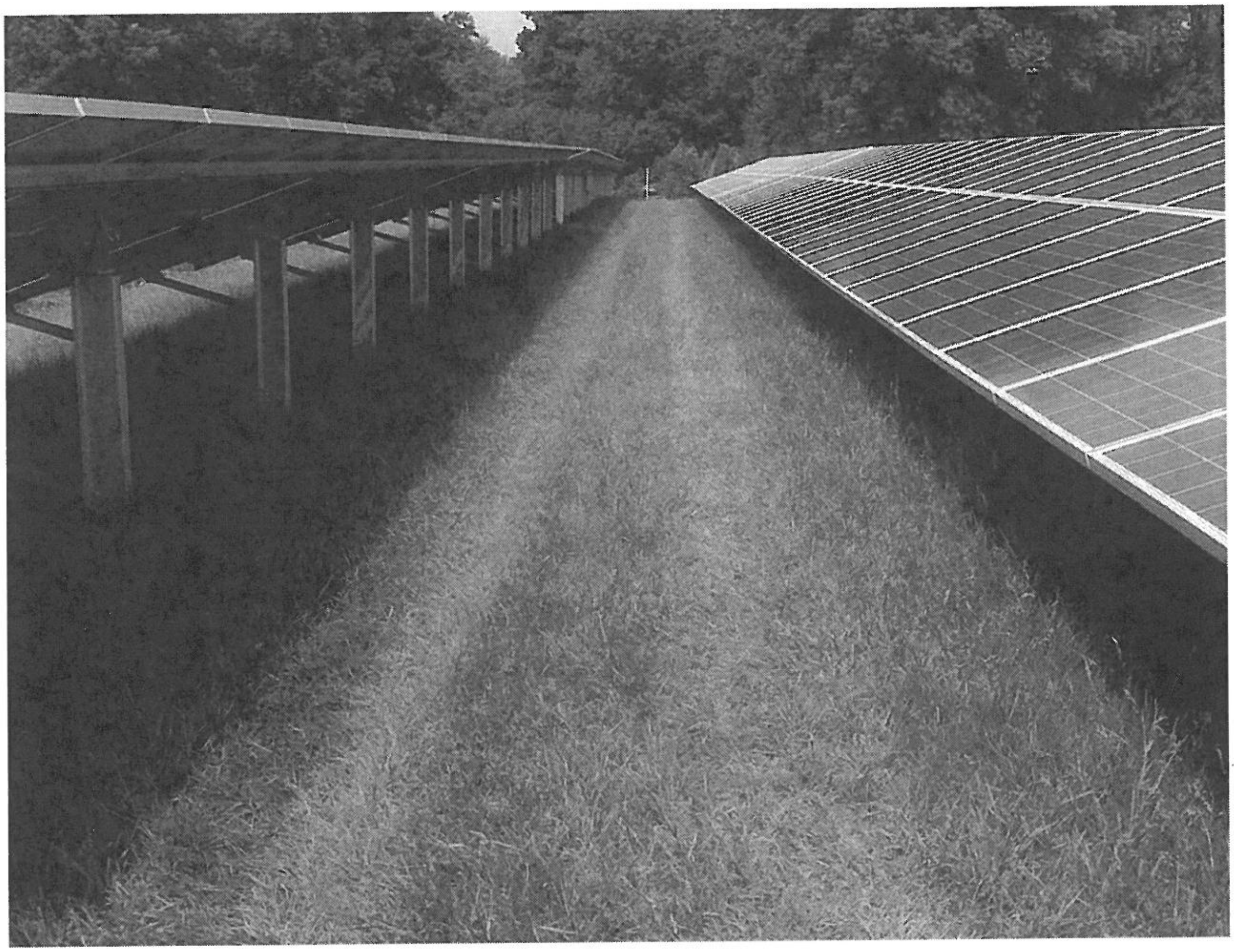

Figure 2

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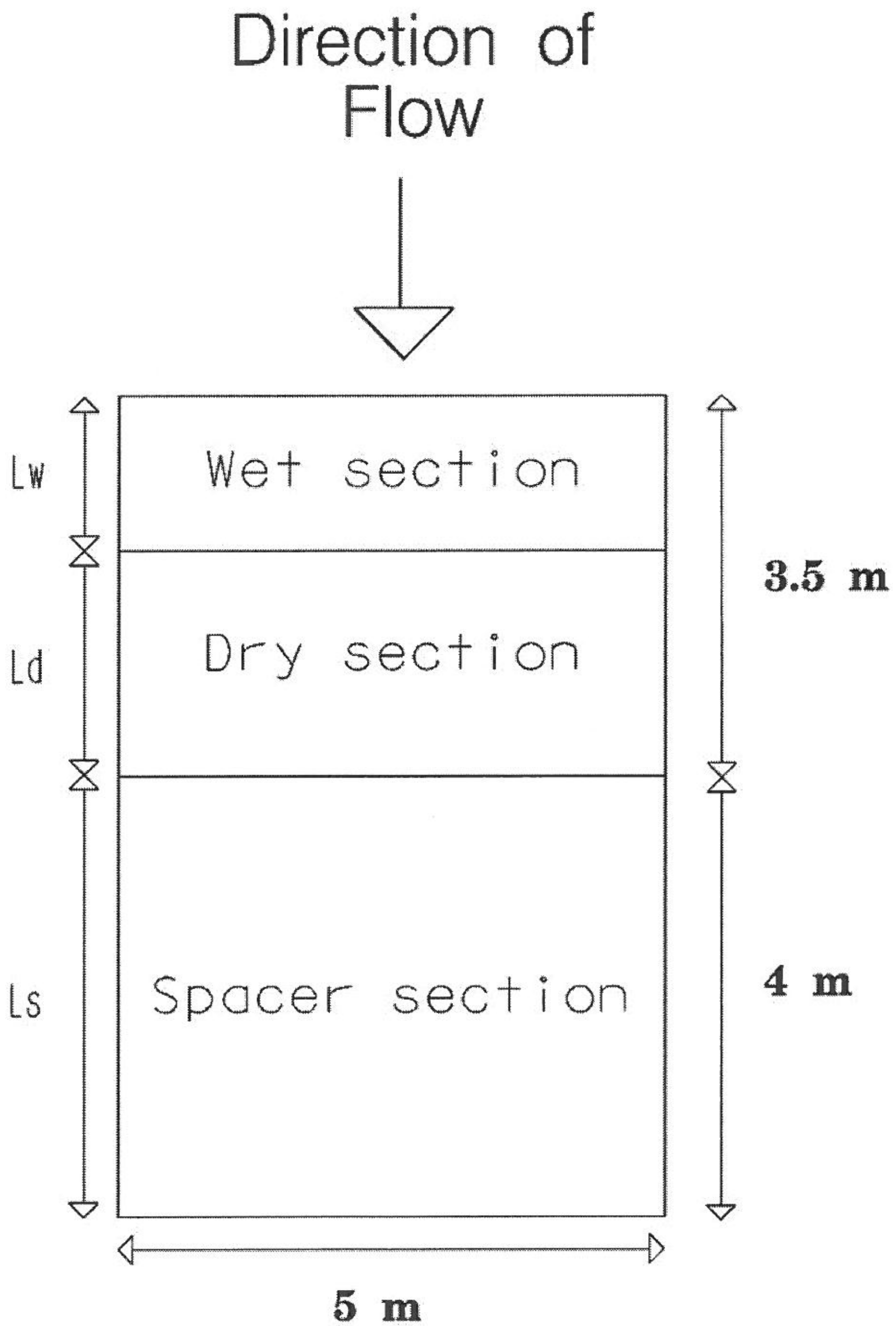

F.gure 3

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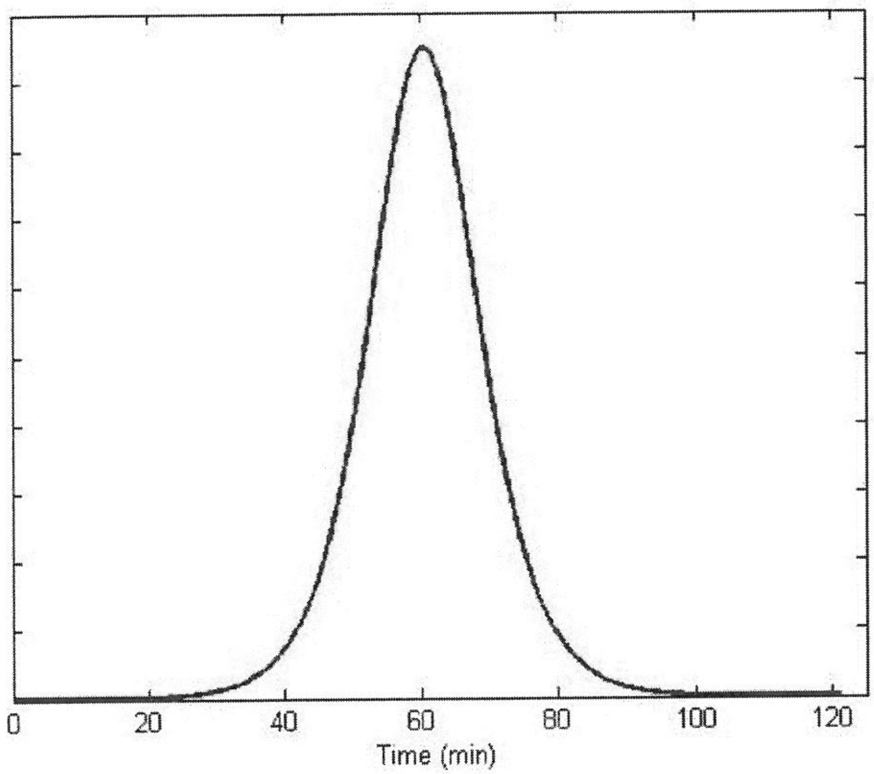

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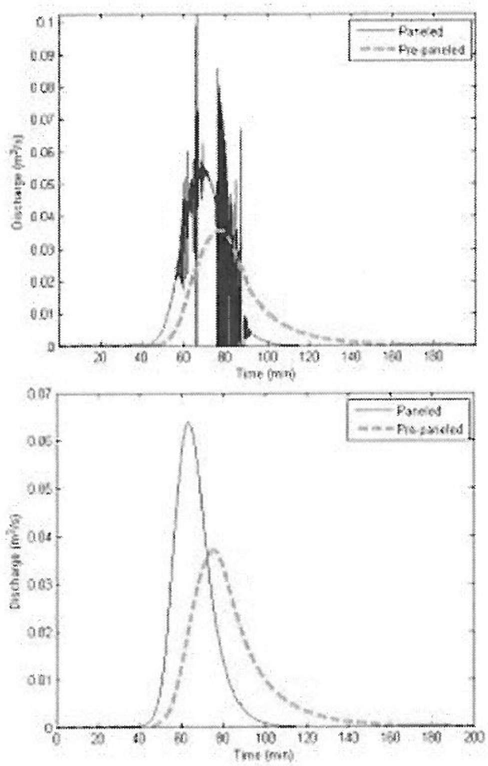

F.gure 5

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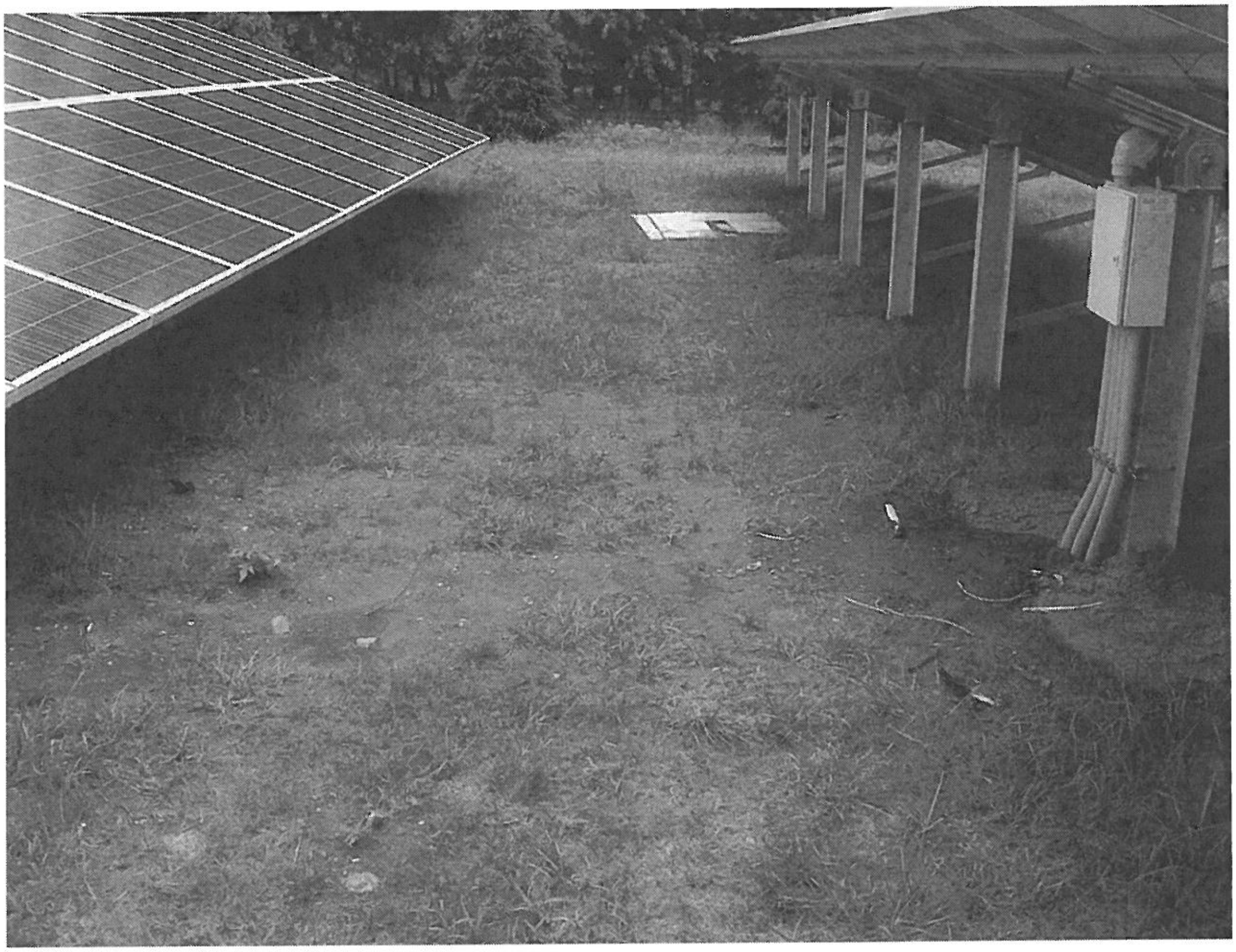

F ure 6

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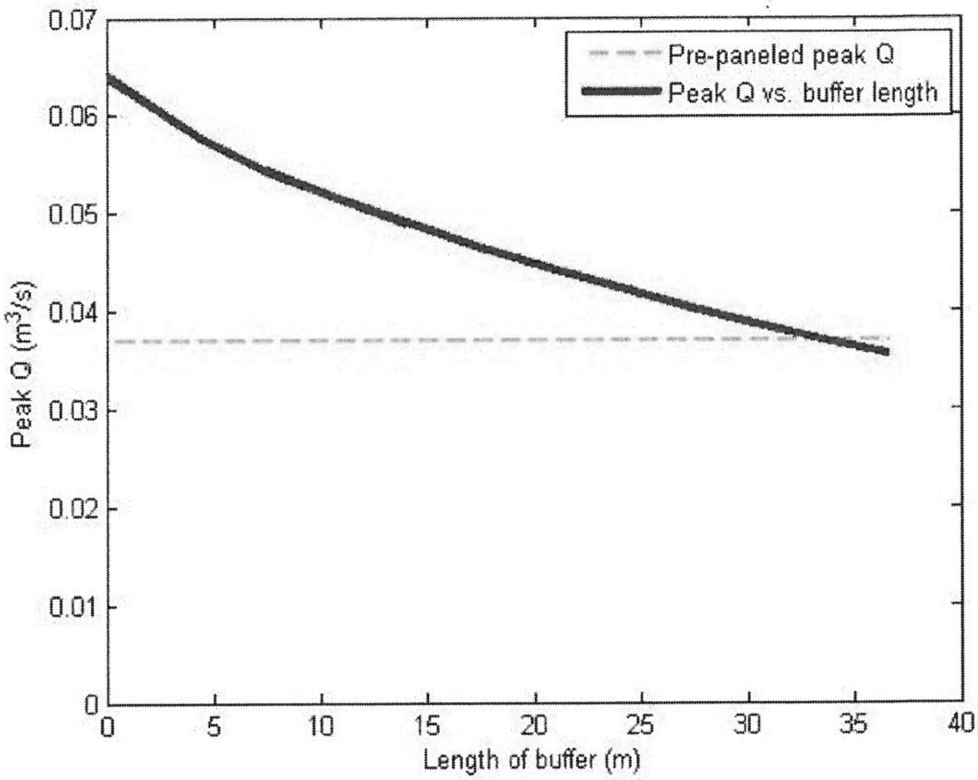

ENGINEERING OPINION

ON

DRAINAGE IMPACTS

Rainbow Solar Farm

February 28, 2012

REGISTERED PROFESSIONAL ENGINEER
9654
OREGON
JULY 14, 1978
MARK D. GRENZ
Renew date: 6-30-13

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Rainbows Solar Energy Farm

Cochise County, Arizona

We were contacted by our Client, Dick Noble to review the proposed Rainbows Solar Energy Farm proposed on property adjacent to his in Cochise County Arizona. Specifically he requested our professional opinion on the potential drainage impacts to his property from the proposed Solar Energy Farm.

It first should be stated that we are a professional engineering firm in the state of Oregon. That our staff engineers are licensed in the states of Oregon, Washington, California, and Nevada. We offer our professional opinions as an aid and assistance in this matter, not in the practice of engineering.

In preparing this opinion, our office has reviewed the five (5) sheet set of plans prepared by Kinctic Engineering & Consultation of Mesa Arizona for the project. (These plans did not bear the stamp or signature of any professional engineer with that firm).

We reviewed the Highway Drainage Design Manual Hydrology prepared by the Arizona Department of Transportation.

We reviewed information prepared for the Journal of Hydrologic Engineering from Lauren M. Cook and Richard H. McCuen on the The Hydrologic Response of Solar Farms.

We reviewed the soils information for the area contained in the USDA Natural Resources Soil Survey for Cochise County, Arizona.

The existing site includes a total of 320 acres of land that has an average slope of just less than 1%. The site is poorly vegetated.

The site has a slight ridge that runs diagonally through the center of the site that directs the surface runoff toward the north boundary and toward the upper east boundary of the site. We reviewed the existing topographic features of the proposed site and identified a total of 7 small sub basins (Subcatchments) that are shown by different colors on Attachment "A". Subcatchment 3S shown in blue is the drainage area that outlets in the northeast corner of the project site under its current undeveloped conditions. Under current conditions, this is the area which drains directly onto Mr. Noble's property.

The soils on the site are predominately Forrest clay loam, with McNeal gravelly sandy loam and some Perilla-Durazo Complex also found. It should be noted that the soils in the lowest portion of the site in the northeast corner are the Forrest clay loam a class "C" soil. This soil has a high shrink-swell potential, a slow permeability, and is very susceptible to erosion when disturbed. *(We have attached pages 95 and 96 from the Cochise County USDA Soils Survey as support)*

The proposed solar farm improvements will cover approximately 51% of the site with panels, thus changing the runoff characteristics of the significantly. The Grading and Drainage Plans, sheets 2 and 3, show the construction of a perimeter access roadway along the east, west, and north boundaries of the site. The detailed sections, B-B, D-D, and E-E show that the site will be graded toward the panel area away from the perimeter boundary with a minimum slope of ½%. This would be consistent with the intended goal of collecting all of the surface runoff from the site and directing it to the proposed detention basin in the northeast corner of the development, "Basin A" as labeled. We have highlighted in "red" the drainage pattern that we believe will occur on the site on Attachment "B".

The proposed "Basin A" has been sized to hold the increased runoff from the site resulting from the additional impervious area during a 100 year storm event. The analysis in the lower left hand corner of Sheet 2 shows that the increased runoff is 17.38 acre feet in volume. Our analysis of the project area would support the reported increase in runoff volume due to the proposed improvements during such an event. However, the proposal to re-grade the perimeter of the site to direct all of the surface runoff to the pond is a very significant change to the present drainage pattern for the site.

Today, the site directs the surface runoff from the project area in the seven (7) different sub basins to the adjoining downstream properties. The water likely exits the site in shallow sheet and concentrated flows distributed along the east and north boundaries. *Our attached Attachment "A" shows the diagramed distribution of the sub basins.*

The proposal would drastically alter that distribution and create a concentrated discharge point at the northeast corner of the proposed solar site. In our analysis of the existing site, we developed the sub basins noted on Attachment "A". Subcatchment 3S is the "blue" area that currently exits the development onto the Noble site.

We prepared Hydrographs of the development site using "HydroCAD Software Solutions". Our analysis was for a Type II, 24-hour 100 year 24 hour Rainfall Event. We analyzed the total site for "pre-development" conditions (total site existing conditions) Subcatchment 2S. We analysis the site for "post-development" conditions as Subcatchment 1S. We also developed hydrographs for all seven

(7) of the sub basins under the "pre-developed" conditions (Subcatchments 3S thru 9S). This was to assimilate approximate runoff distributions onto the adjoining properties.

Today, Subcatchment 3S (blue) under a 100 year event would contribute 14.455 acre-feet of runoff on the Noble property, with a peak flow of 38.84 cfs (cubic feet per second) distributed over 100 feet of frontage for a unit flow of 0.039 cfs. As currently proposed by grading plan, the site will contribute 100% of the runoff from the lower corner of the pond onto the Noble property, that is 80.54 acre-feet of water (less the 19.2 acre-feet of pond volume) for a total of 61.34 acre-feet in one concentrated point flow. That equates to a peak flow of 286.32 cfs which is 7,372 times the current flow rate at that location today. **That's a significant impact!**

Our analysis indicates that the pond's capacity will achieved in a Type II 24-hour 2 year 6 hour rainfall event. After the ponds' capacity is exceeded, 100% of the runoff will exit onto the Noble property as a concentrated point flow and will begin to damage his property. The 2 year peak flow is estimated to be 59.96 cfs which is 1,545 times more concentrated flow than presently enters his property at that same point. A significant impact. It would be our assessment that with this information, no storm water detention will be achieved during a significant event exceeding the 2 year – 6 hour storm.

As noted, the increase in concentrated flow would have major erosion impacts to the soil on the Noble property. The most likely effects would be scouring, cutting and loss of material.

On the Noble property north of the northeast corner of the proposed development are animal pens and a barn where Mr. Noble cares for his wildlife (Gazelles). The proposal would outlet the concentrated flow into the pen area and would direct the major flow at the barn and caretakers home north of the development.

In summary, it is our professional opinion that the proposed solar farm will have a major negative impact on the Noble property as currently proposed.

We would recommend:

(1) The grading and drainage plans for the site be redesigned to more closely mimic the existing drainage pattern as runoff exists the site.

(2) Mr. Noble be afforded an opportunity to review and comment on any future grading and drainage plans prior to permits being issued for the project.

REGISTERED PROFESSIONAL ENGINEER 9654 OREGON JULY 14, 1978 MARK D. GRENZ

PROPOSED PLANS

SITE PLAN
FOR
"RAINBOWS SOLAR ENERGY"
PART OF SECTION 35, TOWNSHIP 23 SOUTH, RANGE 26 EAST, OF THE GILA AND SALT RIVER BASE AND MERIDIAN, COCHISE COUNTY, ARIZONA

SUP LEGAL DESCRIPTION
"THE WEST HALF OF SECTION 35 OF TOWNSHIP 23 SOUTH, RANGE 26 EAST, OF THE GILA AND SALT RIVER BASE AND MERIDIAN, COCHISE COUNTY, ARIZONA".

SITE SUMMARY TABLE

GROSS ACREAGE	:320.79 ACRE
NET ACREAGE	:320.79 ACRE
EXISTING ZONING	:RU-4
PROPOSED ZONING	:SPECIAL USE PERMIT (SUP)
EXISTING LAND USE	:AG – ANIMAL GRAZING

REQUEST
SPECIAL USE PERMIT TO ALLOW FOR SOLAR ENERGY FACILITY DEVELOPMENT.

FLOODPLAIN DATA
THIS PROPERTY IS LOCATED ENTIRELY WITHIN FLOODPLAIN ZONE "X" AS INDICATED ON THE FLOOD INSURANCE RATE MAP PANEL # 04003C2570F, MAP REVISED AUGUST 28, 2008.

ZONE "X" IS DEFINED BY THE FEDERAL EMERGENCY MANAGEMENT AGENCY AS: AREAS DETERMINED TO BE OUTSIDE THE 0.2% ANNUAL CHANCE FLOODPLAIN.

ASSESSOR'S PARCEL NUMBER
APN 401-01-005

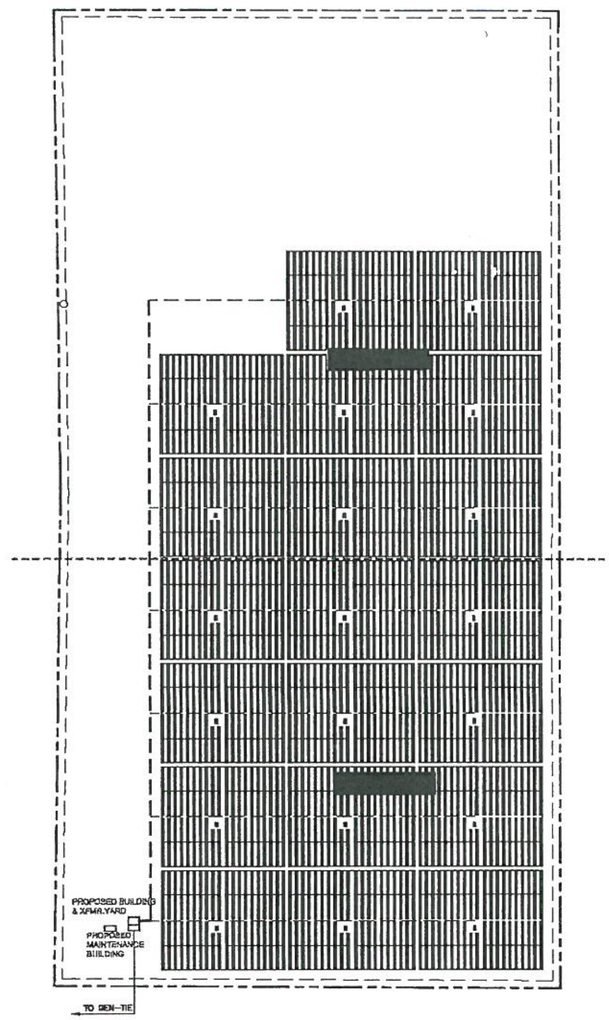
NOTE:
1. DUE TO THE LOW TRAFFIC VOLUME, PARKING WILL NOT BE PROVIDED UPON BUILDOUT OF THIS DEVELOPMENT. TEMPORARY MAINTENANCE CREW SHALL UTILIZE THE GRAVEL ACCESSWAY FOR PARKING.

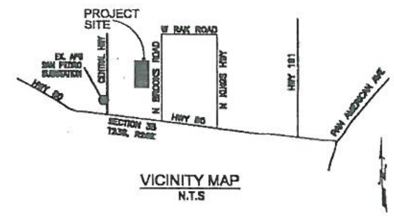
2. THE ONLY UTILITY PROPOSED FOR THIS SITE SHALL BE APS. NO OTHER UTILITIES SHALL BE EMPLOYED OR PROPOSED FOR THIS PROJECT.

3. OUTDOOR LIGHTING IS NOT PROPOSED AT THIS TIME, BUT MIGHT BE USED ON A LIMITED BASIS FOR SECURITY.

4. DURING GRADING AND CONSTRUCTION, DUST CONTROL WILL BE PROVIDED BY WATERING OR OTHER SUITABLE METHODS AND CONTROLLED VEHICULAR SPEEDS. AFTER CONSTRUCTION, DUST CONTROL WILL BE PROVIDED BY CONTROLLED VEHICULAR SPEEDS. THE SOLAR PANELS WILL ACT AS WIND BREAKS, THE PERIMETER FENCING WILL ACT AS A WIND BREAK.

LEGEND
- BOUNDARY LINE
- BUILDING SETBACK LINE (BSL)
- MATCH LINE
- SOLAR PANEL
- PROPOSED ROAD
- CONNECTOR
- UNDERGROUND ELECTRIC LINE MV AC
- ABOVE GROUND ELECTRIC LINE HV AC
- INVERTER STATION OF DIMENSION 10'X22'
- PROPOSED RETENTION BASIN
- EXISTING CONTOURS
- EXISTING GROUND ELEV.
- PROPOSED FINISH GRADE
- EXISTING WELL
- EXISTING POWER POLE
- EXISTING GAS SYSTEM
- PROPOSED FENCE LINE
- PROPOSED GATE
- EXISTING FENCE





VICINITY MAP
N.T.S

KEY MAP
1"=300'

DEVELOPER / OWNER
RAINBOWS SOLAR ENERGY, LLC
2425 OLYMPIC BOULEVARD, SUITE 500E
SANTA MONICA, CA 90404
PHONE: 310-315-2280
ATTN: JOSHUA FIELDS

ENGINEER
KINETIX ENGINEERING & CONSULTATION
12 N. CENTER STREET
MESA, AZ 85201
PHONE: 480-258-6959
FAX: 480-464-5871
ATTN: DAVID M. BOHN

SURVEYOR
ALL PRO SURVEYING, INC.
6635 E. BASELINE ROAD, SUITE 101
MESA, ARIZONA 85206
PHONE: 480-405-3646
FAX: 480-294-9770
ATTN: ROBERT UNGER

SHEET INDEX

SERVICE PROVIDERS

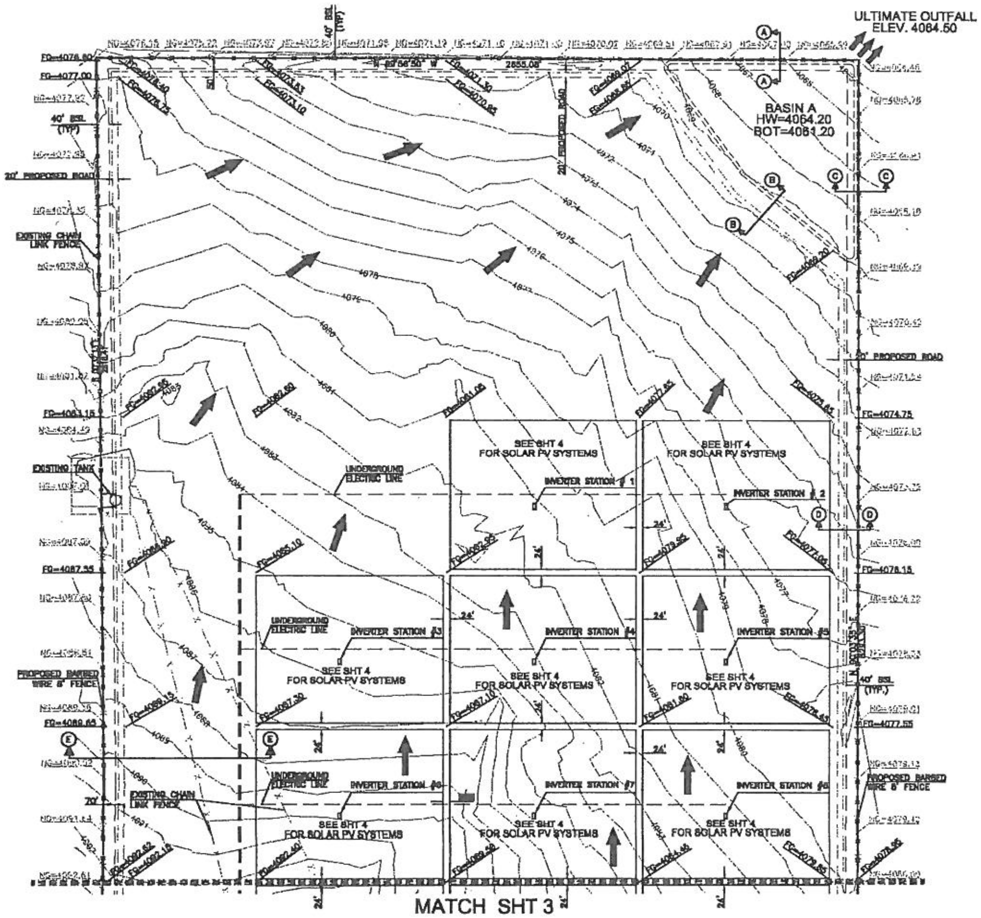
ELECTRIC SERVICES	:APS
WATER	:PRIVATE
SEWER	:SEPTIC

KINETIX
ENGINEERING & CONSULTATION
12 N. CENTER STREET
MESA, ARIZONA 85201
PHONE: 480.258.6959
FAX: 480.464.5871

COVER SHEET

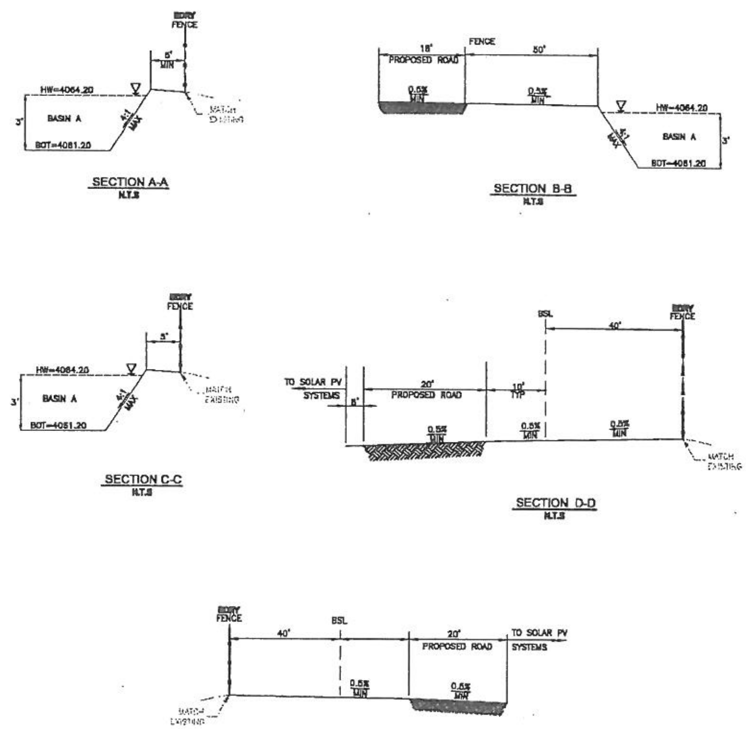
PROJECT: "RAINBOWS SOLAR ENERGY"
COCHISE COUNTY, ARIZONA

JOB NO. 11250
11250CVR01.DWG
SHEET NO. 1



AREA	CONTRIBUTING AREA (ACRES)	RETENTION REQUIRED (AC-FT)	BASIN	AREA TOP (SF)	AREA BOT (SF)	DEPTH (FT)	RETENTION PROVIDED (AC-FT)	EXCESS (%)
100YR – 1 HR RETENTION CALCULATIONS:								
A	320.79	17.38	A	292,168	284,143	3.0	19.16	10%
TOTAL	320.79	17.38					19.16	10%

RETENTION REQUIRED EQUATION: V=C*(P/12)*A
WHERE: V = VOLUME (AC-FT)
C = 0.25
PRE-DEVELOPMENT C VALUE = 0.41; POST-DEVELOPMENT C VALUE = 0.66
THEREFORE: C = 0.66-0.41 = 0.25
P = 2.60 INCHES
A = 320.79 ACRES (CONTRIBUTING AREA)
RETENTION PROVIDED EQUATION: V = (AREA TOP + AREA BOTTOM)/2 * DEPTH (SFT)



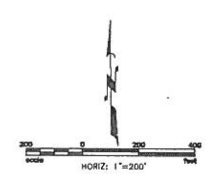
SECTION A-A
N.T.S

SECTION B-B
N.T.S

SECTION C-C
N.T.S

SECTION D-D
N.T.S

SECTION E-E
N.T.S

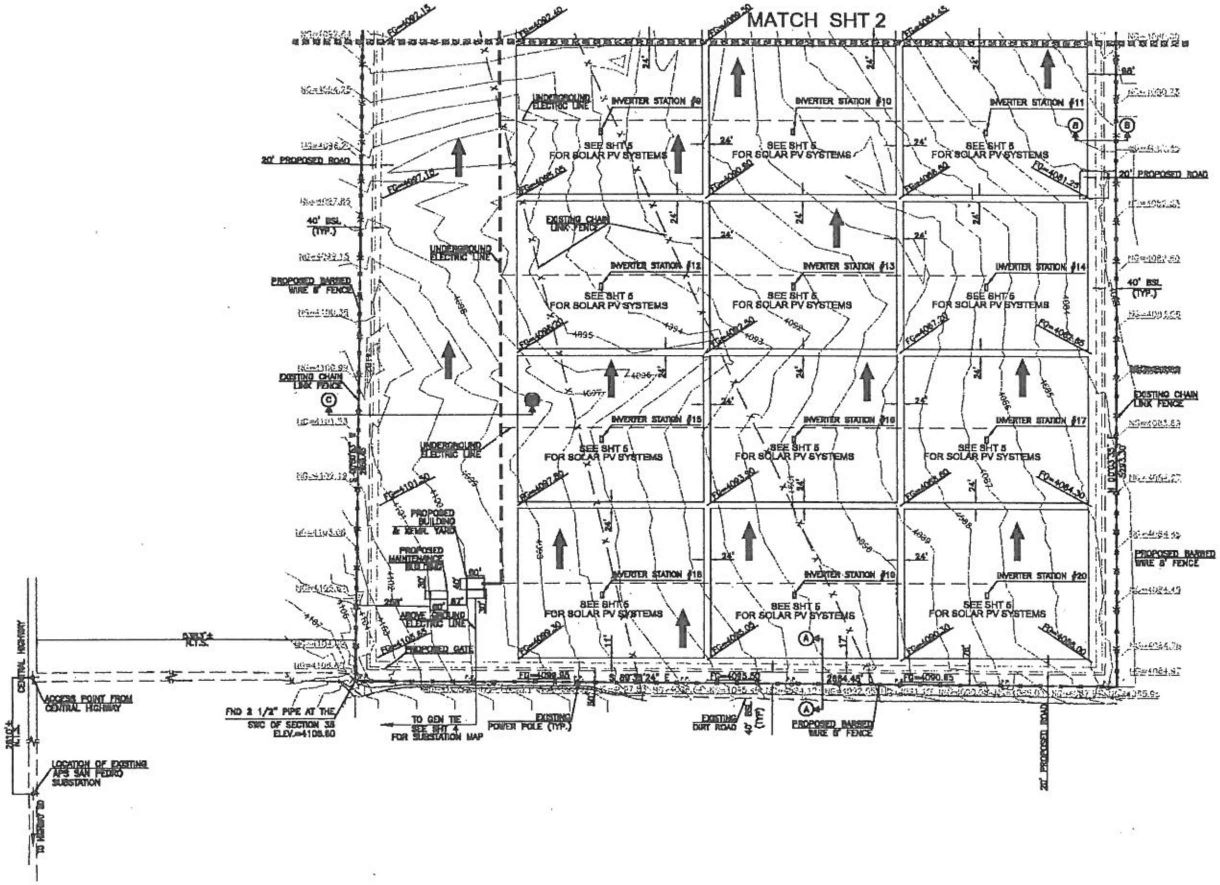


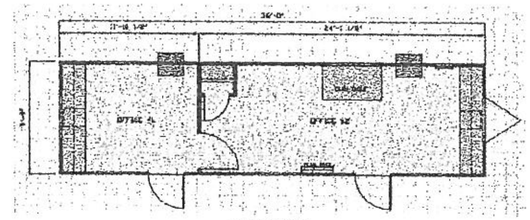
KINETIX
ENGINEERING & CONSULTATION
12 N. CENTER STREET
MESA, ARIZONA 85201
PHONE: 480.258.6959
FAX: 480.464.5871

GRADING & DRAINAGE PLAN

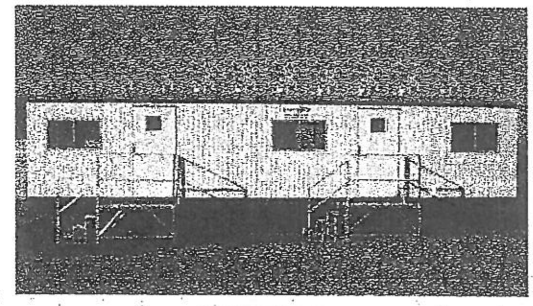
PROJECT: "RAINBOWS SOLAR ENERGY"
COCHISE COUNTY, ARIZONA

JOB NO. 11250
11250GP02.DWG
SHEET NO. 2
2 OF 5





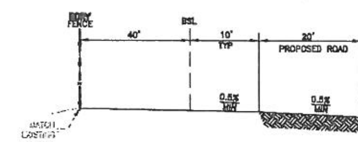
FLOOR PLAN



OFFICE ELEVATION VIEW

PORTABLE OFFICE DETAIL

N.T.S



SECTION A-A

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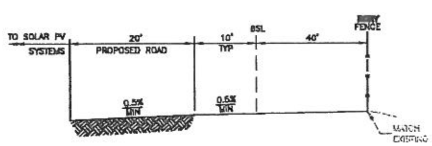

SECTION B-B

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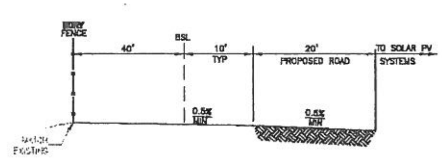

SECTION C-C

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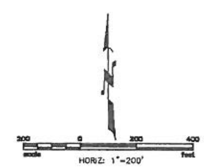


KINCTIX
ENGINEERING & CONSULTATION
12 N. CENTER STREET
MESA, ARIZONA 85201
PHONE: 480.258.6959
FAX: 480.464.5871

GRADING & DRAINAGE PLAN

PROJECT: "RAINBOWS SOLAR ENERGY"

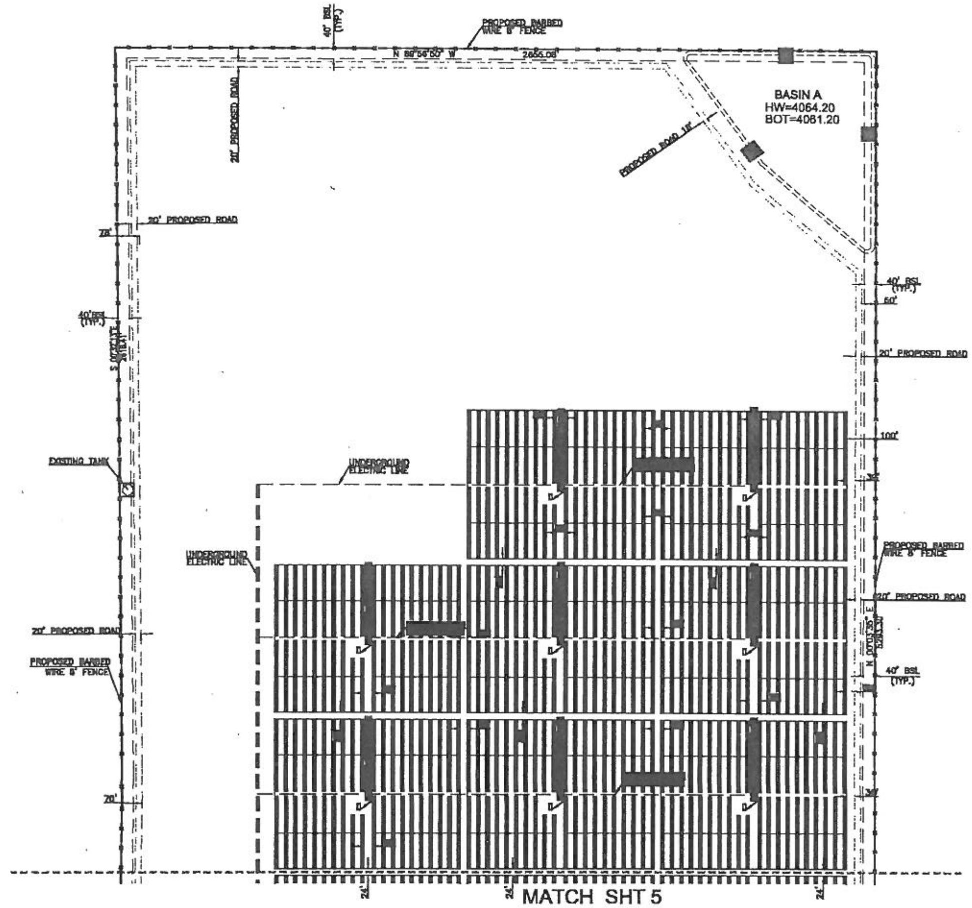
COCHISE COUNTY, ARIZONA

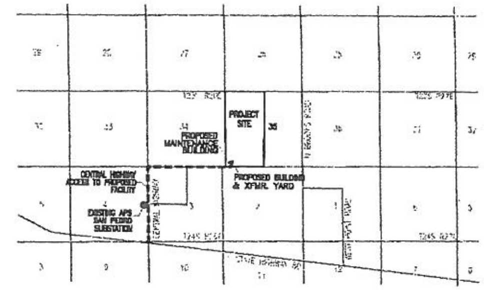
JOB NO. 11250

11250GP03.DWG

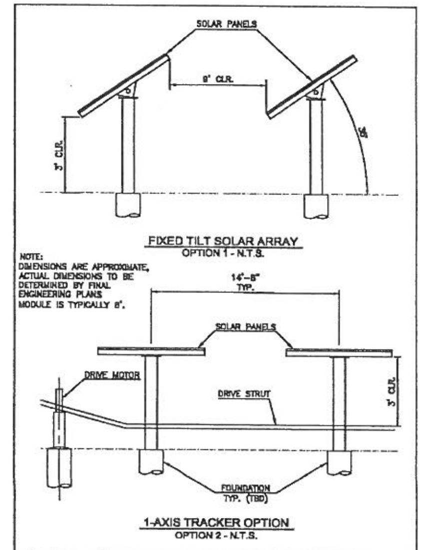
SHEET NO. 3

3 OF 5

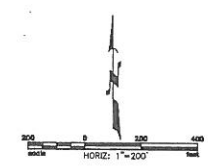




SUBSTATION MAP



SOLAR PANEL CROSS SECTION



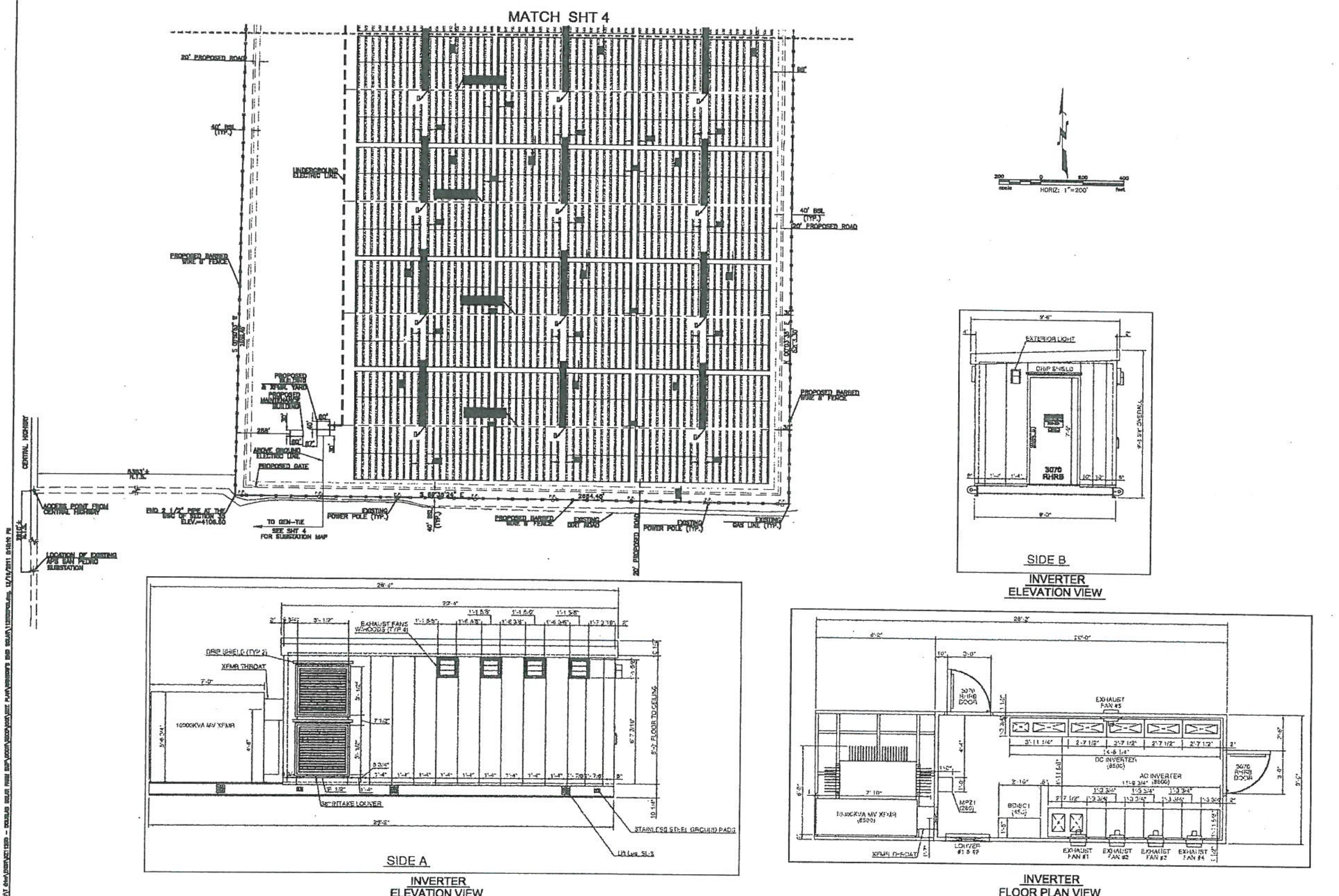
KINETIX
ENGINEERING & CONSULTATION
12 N. CENTER STREET
MESA, ARIZONA 85201
PHONE: 480.258.6959
FAX: 480.464.5871

SITE PLAN

PROJECT: "RAINBOWS SOLAR ENERGY"
COCHISE COUNTY, ARIZONA

Job No. 11250
Drawn By KHM
Checked DB

JOB NO. 11250
11250SP04.DWG
SHEET NO. 4
4 OF 5



KINETIX
ENGINEERING & CONSULTATION
12 N. CENTER STREET
MESA, ARIZONA 85201
PHONE: 480.258.6959
FAX: 480.464.5871

SITE PLAN

PROJECT: "RAINBOWS SOLAR ENERGY"
COCHISE COUNTY, ARIZONA

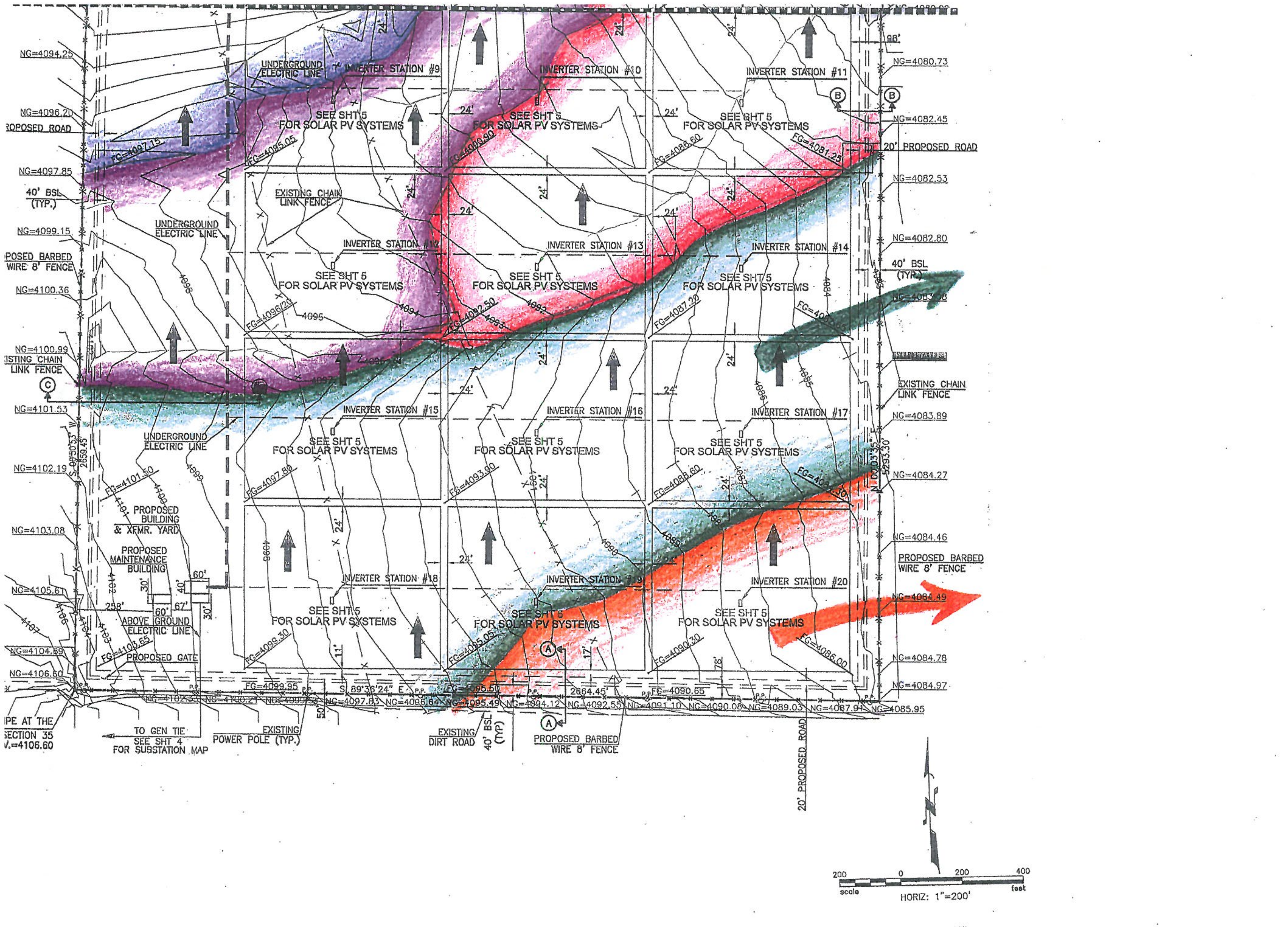
JOB NO. 11250

11250SP05.DWG

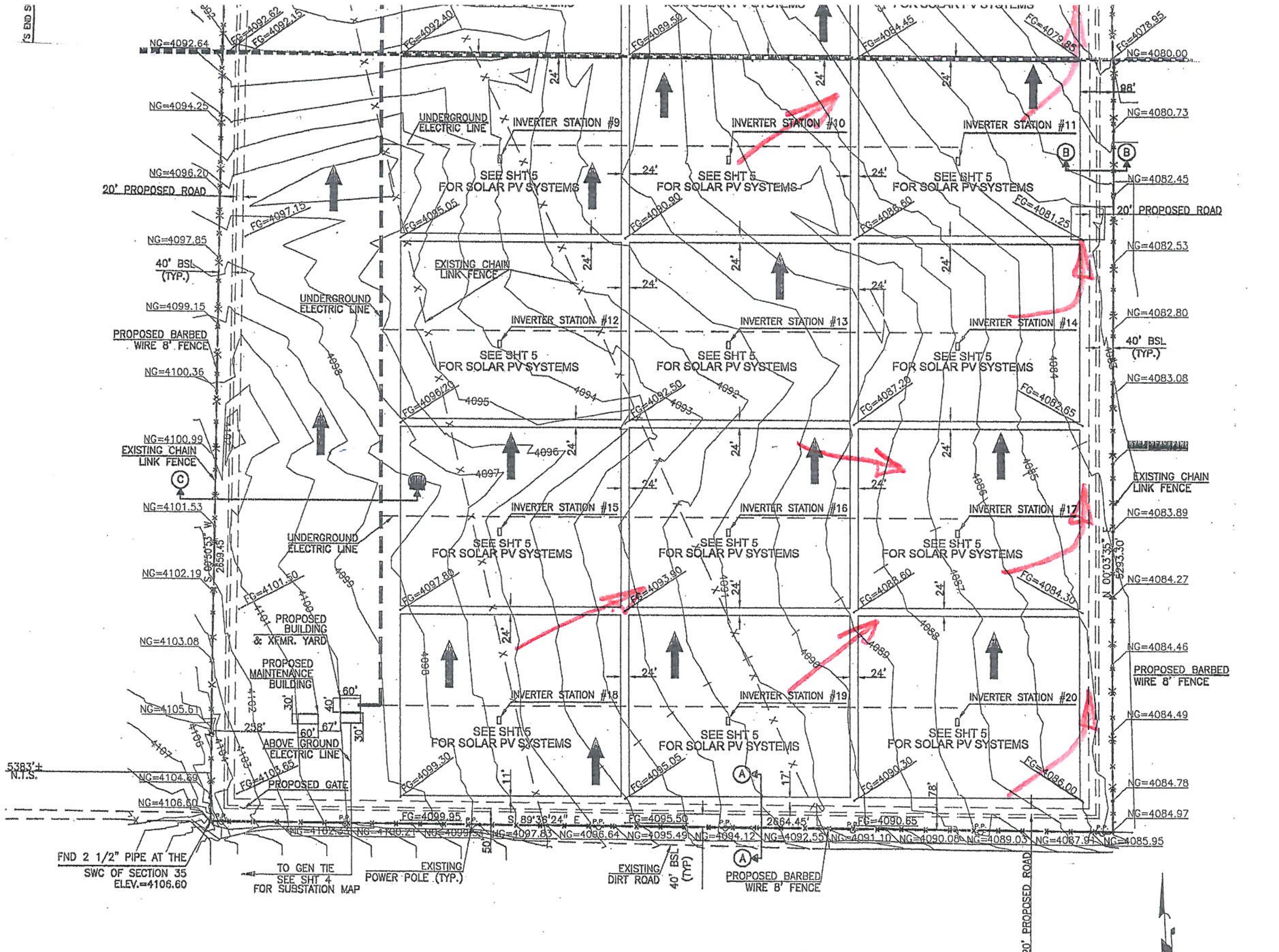
SHEET NO. 5

5 OF 5

ATTACHMENT A: EXISTING DRAINAGE AND SUB BASINS



INVERTER STATION #9
INVERTER STATION #10
INVERTER STATION #11
INVERTER STATION #12
INVERTER STATION #13
INVERTER STATION #14
INVERTER STATION #15
INVERTER STATION #16
INVERTER STATION #17
INVERTER STATION #18
INVERTER STATION #19
INVERTER STATION #20
SEE SHT 5 FOR SOLAR PV SYSTEMS
UNDERGROUND ELECTRIC LINE
EXISTING CHAIN LINK FENCE
PROPOSED BARBED WIRE 8' FENCE
40' BSL (TYP.)
20' PROPOSED ROAD
PROPOSED BUILDING & XFMR. YARD
PROPOSED MAINTENANCE BUILDING
ABOVE GROUND ELECTRIC LINE
PROPOSED GATE
TO GEN TIE SEE SHT 4 FOR SUBSTATION MAP
EXISTING POWER POLE (TYP.)
EXISTING DIRT ROAD
S 89°36'24" E 2664.45'
N 00°03'35" E 5293.30'
S 00°30'53" W 2659.45'
NG=4094.25
NG=4096.20
NG=4097.85
NG=4099.15
NG=4100.36
NG=4100.99
NG=4101.53
NG=4102.19
NG=4103.08
NG=4105.61
NG=4104.69
NG=4106.60
NG=4080.73
NG=4082.45
NG=4082.53
NG=4082.80
NG=4083.89
NG=4084.27
NG=4084.46
NG=4084.49
NG=4084.78
NG=4084.97
NG=4085.95
FG=4097.15
FG=4095.05
FG=4089.90
FG=4086.60
FG=4081.25
FG=4096.20
FG=4092.50
FG=4087.20
FG=4097.80
FG=4093.90
FG=4088.60
FG=4101.50
FG=4099.30
FG=4095.05
FG=4090.30
FG=4086.00
FG=4103.65
FG=4099.95
FG=4096.50
FG=4090.65
HORIZ: 1"=200'



PROPOSED DRAINAGE FLOW

ATTACHMENT C: HYDROGRAPH ANALYSES

MULTI/TECH
ENGINEERING SERVICES, INC.

CONSULTANTS
1155 13th Street, S.E.
Salem, Oregon 97302
(503) 363-9227

Subcatchment Summary

This attachment contains the hydrographs for the approximate subcatchments of the Rainbows Solar Engery property for the current conditions. The topography of the site currently causes the runoff to drain in a sheet flow pattern in approximately 7 directions. These areas have been colored and can be seen on the following plan. A summary of each subcatchment is listed below. The hydrographs can be seen in this order in the following pages.

Post-Development (Total): Subcatchment 1S

The entire site of 320.79 acres with a pro-rated curve number based on the proposed area for the solar panels and access roadways. The proposed grading and drainage for the solar farm directs all of the runoff from the site towards a proposed detention basin located in the northeast corner of the site. This pond has an outflow elevation set to the existing elevation of the ground. The hydrograph analysis for the total site based on the 100-year 24 hour rainfall event and the pro-rated curve number indicates the runoff will be generated at a peak flow rate of 286.32 cubic feet per second with a total runoff volume of 80.542 acre feet. All of the water is proposed to drain to Mr. Noble's property, located northeast of the solar farm property.

The entire property was also analyzed for the 2-year g hour storm event, given the same conditions. The runoff generated from this event will have a peak flow rate of 59.96 cubic feet per second with a total runoff volume of 18.261 acre feet. Any event larger than this event will result in the overflow of the proposed detention basin, causing all the runoff to overflow at peak flow rates onto Mr. Noble's property.

Pre-Development (Total): Subcatchment 2S

The entire site of 320.79 acres was analyzed under existing conditions to determine was the total runoff generated in a 100-year 24 hour event would be. For the 100-year 24 hour event, the runoff is generated at a peak flow of 176.29 cubic feet per second with a total volume of 65.616 acre feet. This runoff is discharged across almost the entire eastern and northern edges of the property.

Orange: Subcatchment 4S

A 14.510 acre area located on the southeast corner of the property. Runoff from this area drains to the east of the solar farm property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 7.97 cubic feet per second with a total runoff volume of 2.968 acre feet.

Evergreen: Subcatchment 5S

A 62.110 acrea area which runs across the south end of the property. Runoff from this area drains to the east of the solar farm property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 34.13 cubic feet per second with a total runoff volume of 12.704 acre feet.

Red: Subcatchment 6S

A 38.130 acre area located on the east side of the property. Runoff from this area drains in a northeastern direction on the property direction east of the solar farm property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 20.95 cubic feet per second with a total runoff volume of 7.799 acre feet.

Lavender: Subcatchment 7S

A 69.20 acre area which runs from the southwest edge of the property to the northeast side of the property. Runoff from this area drains to the northeast onto the property located to the east of the solar farm property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 38.03 cubic feet per second with a total runoff volume of 14.155 acre feet.

Blue: Subcatchment 3S

A 70.670 acre area which runs from the west edge of the property to the northeast corner of the property. This subcatchment represents the area which currently contributes runoff to the Noble property. Runoff from this area drains to the northeast corner onto Mr. Noble's property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 38.84 cubic feet per second with a total runoff volume of 14.455 acre feet.

Yellow: Subcatchment 8S

A 43.270 acre area which runs for the west edge of the property to the north. Runoff from this area drains to the property located directly north of the solar farm property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 23.78 cubic feet per second with a total runoff volume of 8.851 acre feet.

Green: Subcatchment 9S

A 20.760 acre area located along the northwest edge of the property. Runoff from this area drains to the properties located directly north and west of the solar farm property. For the 100-year 24 hour event, the runoff is generated at a peak flow rate of 11.41 cubic feet per second with a total runoff volume of 4.246 acre feet.

Summary for Subcatchment 1S: Post-Development

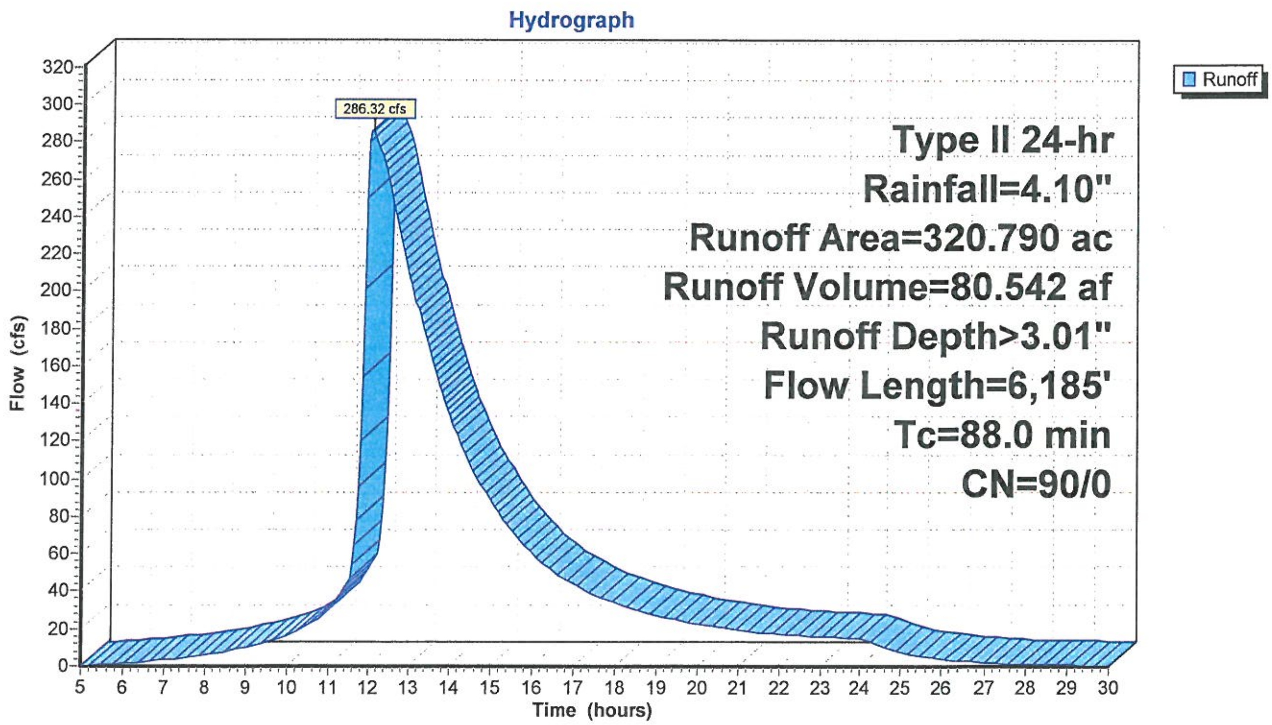
Runoff = 286.32 cfs @ 12.06 hrs, Volume= 80.542 af, Depth> 3.01"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.10"

Area (ac)	CN	Description
164.140	91	Gravel roads, HSG D
156.650	88	Desert shrub range, Poor, HSG D
320.790	90	Weighted Average
320.790	90	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
25.7	2,210	0.0050	1.44		**Shallow Concentrated Flow, West Roadway** Paved Kv= 20.3 fps
19.6	1,685	0.0050	1.44		**Shallow Concentrated Flow, West Road** Paved Kv= 20.3 fps
42.7	2,290	0.0080	0.89		**Shallow Concentrated Flow, Flow to Basin** Nearly Bare & Untilled Kv= 10.0 fps
88.0	6,185	Total			

Subcatchment 1S: Post-Development



Hydrograph for Subcatchment 1S: Post-Development

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.20
5.50	0.29	0.00	0.00	0.70
6.00	0.33	0.01	0.00	1.43
6.50	0.37	0.02	0.00	2.37
7.00	0.41	0.03	0.00	3.47
7.50	0.45	0.04	0.00	4.71
8.00	0.49	0.05	0.00	6.07
8.50	0.54	0.07	0.00	7.81
9.00	0.60	0.10	0.00	10.29
9.50	0.67	0.13	0.00	13.05
10.00	0.74	0.17	0.00	16.32
10.50	0.84	0.22	0.00	21.43
11.00	0.96	0.30	0.00	29.69
11.50	1.16	0.43	0.00	45.62
12.00	2.72	1.73	0.00	**279.96**
12.50	3.01	2.00	0.00	**255.70**
13.00	3.17	2.14	0.00	208.23
13.50	3.28	2.24	0.00	167.37
14.00	3.36	2.32	0.00	134.07
14.50	3.43	2.39	0.00	107.96
15.00	3.50	2.45	0.00	88.17
15.50	3.56	2.50	0.00	72.87
16.00	3.61	2.55	0.00	60.74
16.50	3.65	2.59	0.00	51.26
17.00	3.70	2.63	0.00	44.07
17.50	3.74	2.67	0.00	38.52
18.00	3.78	2.71	0.00	34.13
18.50	3.81	2.74	0.00	30.56
19.00	3.84	2.77	0.00	27.58
19.50	3.88	2.80	0.00	25.01
20.00	3.90	2.83	0.00	22.73
20.50	3.93	2.85	0.00	20.84
21.00	3.96	2.88	0.00	19.40
21.50	3.98	2.90	0.00	18.29
22.00	4.01	2.92	0.00	17.41
22.50	4.03	2.95	0.00	16.70
23.00	4.05	2.97	0.00	16.11
23.50	4.08	2.99	0.00	15.59
24.00	**4.10**	**3.01**	0.00	15.14
24.50	4.10	3.01	0.00	10.94
25.00	4.10	3.01	0.00	7.78
25.50	4.10	3.01	0.00	5.53
26.00	4.10	3.01	0.00	3.93
26.50	4.10	3.01	0.00	2.80
27.00	4.10	3.01	0.00	1.99
27.50	4.10	3.01	0.00	1.41
28.00	4.10	3.01	0.00	1.01
28.50	4.10	3.01	0.00	0.72
29.00	4.10	3.01	0.00	0.51
29.50	4.10	3.01	0.00	0.36
30.00	4.10	3.01	0.00	0.26

Summary for Subcatchment 1S: Post-Development

Runoff = 59.96 cfs @ 12.08 hrs, Volume= 18.261 af, Depth> 0.68"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 2 yr 6 hr Rainfall=1.50"

Area (ac)	CN	Description
164.140	91	Gravel roads, HSG D
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320.790	90	Weighted Average
320.790	90	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
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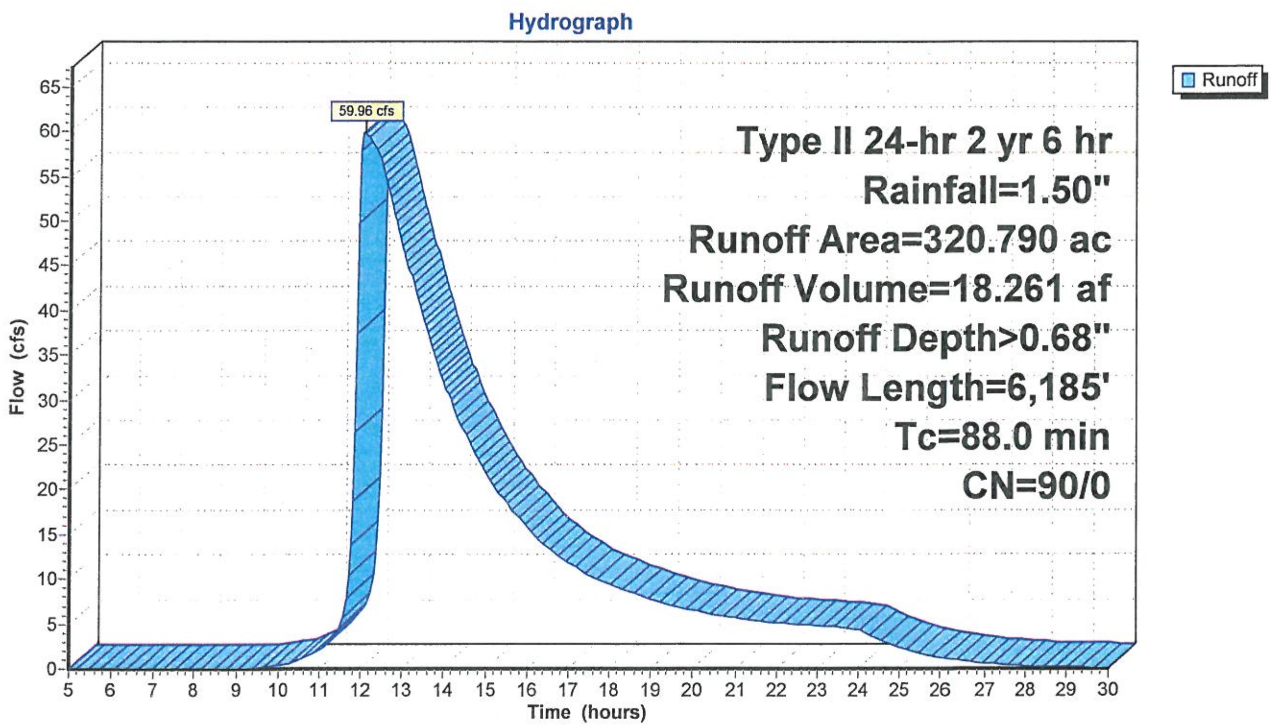
19.6	1,685	0.0050	1.44		**Shallow Concentrated Flow, West Road** Paved Kv= 20.3 fps
42.7	2,290	0.0080	0.89		**Shallow Concentrated Flow, Flow to Basin** Nearly Bare & Untilled Kv= 10.0 fps
88.0	6,185	Total			

Subcatchment 1S: Post-Development



Hydrograph for Subcatchment 1S: Post-Development

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.09	0.00	**0.00**	0.00
5.50	0.11	0.00	0.00	0.00
6.00	0.12	0.00	0.00	0.00
6.50	0.13	0.00	0.00	0.00
7.00	0.15	0.00	0.00	0.00
7.50	0.16	0.00	0.00	0.00
8.00	0.18	0.00	0.00	0.00
8.50	0.20	0.00	0.00	0.00
9.00	0.22	0.00	0.00	0.00
9.50	0.24	0.00	0.00	0.08
10.00	0.27	0.00	0.00	0.36
10.50	0.31	0.01	0.00	0.95
11.00	0.35	0.01	0.00	2.11
11.50	0.42	0.03	0.00	4.71
12.00	0.99	0.32	0.00	**57.82**
12.50	1.10	0.39	0.00	**56.29**
13.00	1.16	0.43	0.00	47.33
13.50	1.20	0.46	0.00	39.07
14.00	1.23	0.48	0.00	32.05
14.50	1.26	0.50	0.00	26.40
15.00	1.28	0.52	0.00	22.05
15.50	1.30	0.53	0.00	18.62
16.00	1.32	0.55	0.00	15.83
16.50	1.34	0.56	0.00	13.61
17.00	1.35	0.57	0.00	11.91
17.50	1.37	0.58	0.00	10.58
18.00	1.38	0.59	0.00	9.51
18.50	1.39	0.60	0.00	8.62
19.00	1.41	0.61	0.00	7.86
19.50	1.42	0.62	0.00	7.19
20.00	1.43	0.63	0.00	6.58
20.50	1.44	0.63	0.00	6.07
21.00	1.45	0.64	0.00	5.69
21.50	1.46	0.65	0.00	5.39
22.00	1.47	0.66	0.00	5.15
22.50	1.47	0.66	0.00	4.96
23.00	1.48	0.67	0.00	4.80
23.50	1.49	0.68	0.00	4.66
24.00	**1.50**	**0.68**	0.00	4.53
24.50	1.50	0.68	0.00	3.28
25.00	1.50	0.68	0.00	2.33
25.50	1.50	0.68	0.00	1.66
26.00	1.50	0.68	0.00	1.18
26.50	1.50	0.68	0.00	0.84
27.00	1.50	0.68	0.00	0.60
27.50	1.50	0.68	0.00	0.42
28.00	1.50	0.68	0.00	0.30
28.50	1.50	0.68	0.00	0.21
29.00	1.50	0.68	0.00	0.15
29.50	1.50	0.68	0.00	0.11
30.00	1.50	0.68	0.00	0.08

Summary for Subcatchment 2S: Pre-Development (Total)

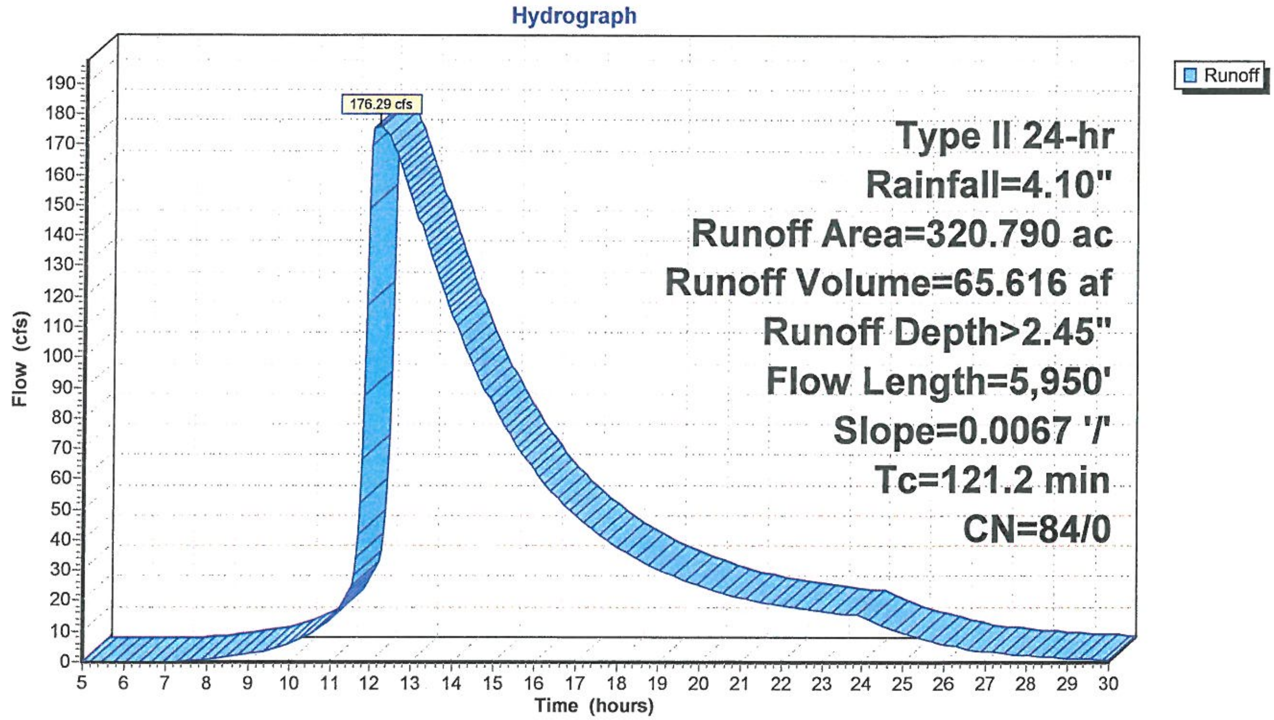
Runoff = 176.29 cfs @ 12.19 hrs, Volume= 65.616 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr Rainfall=4.10"

Area (ac)	CN	Description
320.790	84	Desert shrub range, Good, HSG D
320.790	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 2S: Pre-Development (Total)



Hydrograph for Subcatchment 2S: Pre-Development (Total)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.04
7.50	0.45	0.00	0.00	0.30
8.00	0.49	0.01	0.00	0.77
8.50	0.54	0.01	0.00	1.51
9.00	0.60	0.02	0.00	2.65
9.50	0.67	0.04	0.00	4.12
10.00	0.74	0.06	0.00	6.01
10.50	0.84	0.09	0.00	8.94
11.00	0.96	0.14	0.00	13.77
11.50	1.16	0.23	0.00	23.25
12.00	2.72	1.29	0.00	**169.42**
12.50	3.01	1.53	0.00	**170.80**
13.00	3.17	1.65	0.00	151.42
13.50	3.28	1.75	0.00	131.49
14.00	3.36	1.82	0.00	113.06
14.50	3.43	1.88	0.00	97.01
15.00	3.50	1.94	0.00	83.65
15.50	3.56	1.99	0.00	72.38
16.00	3.61	2.03	0.00	62.73
16.50	3.65	2.07	0.00	54.60
17.00	3.70	2.11	0.00	47.96
17.50	3.74	2.14	0.00	42.47
18.00	3.78	2.17	0.00	37.88
18.50	3.81	2.21	0.00	33.98
19.00	3.84	2.23	0.00	30.64
19.50	3.88	2.26	0.00	27.71
20.00	3.90	2.29	0.00	25.12
20.50	3.93	2.31	0.00	22.90
21.00	3.96	2.33	0.00	21.10
21.50	3.98	2.35	0.00	19.64
22.00	4.01	2.38	0.00	18.44
22.50	4.03	2.40	0.00	17.45
23.00	4.05	2.42	0.00	16.61
23.50	4.08	2.44	0.00	15.89
24.00	**4.10**	**2.46**	0.00	15.27
24.50	4.10	2.46	0.00	12.05
25.00	4.10	2.46	0.00	9.41
25.50	4.10	2.46	0.00	7.34
26.00	4.10	2.46	0.00	5.73
26.50	4.10	2.46	0.00	4.48
27.00	4.10	2.46	0.00	3.49
27.50	4.10	2.46	0.00	2.73
28.00	4.10	2.46	0.00	2.13
28.50	4.10	2.46	0.00	1.66
29.00	4.10	2.46	0.00	1.30
29.50	4.10	2.46	0.00	1.01
30.00	4.10	2.46	0.00	0.79

Summary for Subcatchment 4S: Pre-Development (Orange)

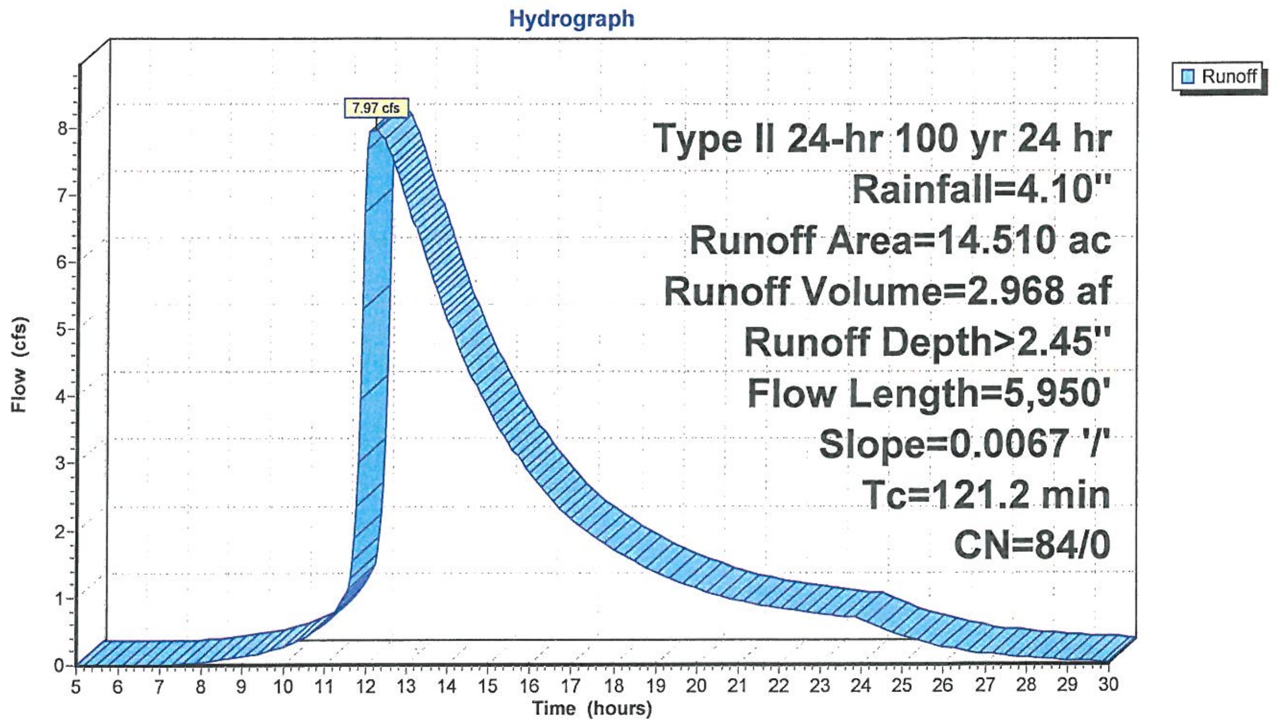
Runoff = 7.97 cfs @ 12.19 hrs, Volume= 2.968 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
14.510	84	Desert shrub range, Good, HSG D
14.510	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 4S: Pre-Development (Orange)



Hydrograph for Subcatchment 4S: Pre-Development (Orange)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.00
7.50	0.45	0.00	0.00	0.01
8.00	0.49	0.01	0.00	0.03
8.50	0.54	0.01	0.00	0.07
9.00	0.60	0.02	0.00	0.12
9.50	0.67	0.04	0.00	0.19
10.00	0.74	0.06	0.00	0.27
10.50	0.84	0.09	0.00	0.40
11.00	0.96	0.14	0.00	0.62
11.50	1.16	0.23	0.00	1.05
12.00	2.72	1.29	0.00	**7.66**
12.50	3.01	1.53	0.00	**7.73**
13.00	3.17	1.65	0.00	6.85
13.50	3.28	1.75	0.00	5.95
14.00	3.36	1.82	0.00	5.11
14.50	3.43	1.88	0.00	4.39
15.00	3.50	1.94	0.00	3.78
15.50	3.56	1.99	0.00	3.27
16.00	3.61	2.03	0.00	2.84
16.50	3.65	2.07	0.00	2.47
17.00	3.70	2.11	0.00	2.17
17.50	3.74	2.14	0.00	1.92
18.00	3.78	2.17	0.00	1.71
18.50	3.81	2.21	0.00	1.54
19.00	3.84	2.23	0.00	1.39
19.50	3.88	2.26	0.00	1.25
20.00	3.90	2.29	0.00	1.14
20.50	3.93	2.31	0.00	1.04
21.00	3.96	2.33	0.00	0.95
21.50	3.98	2.35	0.00	0.89
22.00	4.01	2.38	0.00	0.83
22.50	4.03	2.40	0.00	0.79
23.00	4.05	2.42	0.00	0.75
23.50	4.08	2.44	0.00	0.72
24.00	**4.10**	**2.46**	0.00	0.69
24.50	4.10	2.46	0.00	0.54
25.00	4.10	2.46	0.00	0.43
25.50	4.10	2.46	0.00	0.33
26.00	4.10	2.46	0.00	0.26
26.50	4.10	2.46	0.00	0.20
27.00	4.10	2.46	0.00	0.16
27.50	4.10	2.46	0.00	0.12
28.00	4.10	2.46	0.00	0.10
28.50	4.10	2.46	0.00	0.08
29.00	4.10	2.46	0.00	0.06
29.50	4.10	2.46	0.00	0.05
30.00	4.10	2.46	0.00	0.04

Summary for Subcatchment 5S: Pre-Development (Evergreen)

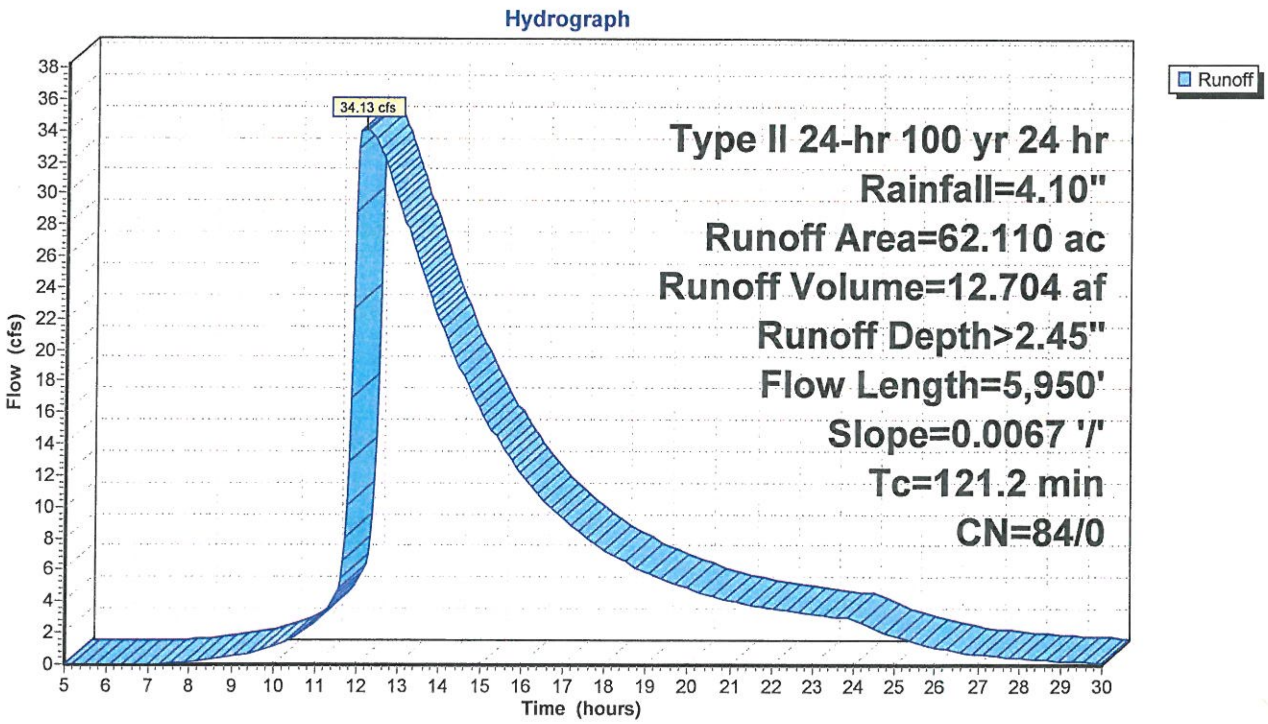
Runoff = 34.13 cfs @ 12.19 hrs, Volume= 12.704 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
62.110	84	Desert shrub range, Good, HSG D
62.110	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 5S: Pre-Development (Evergreen)



Hydrograph for Subcatchment 5S: Pre-Development (Evergreen)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.01
7.50	0.45	0.00	0.00	0.06
8.00	0.49	0.01	0.00	0.15
8.50	0.54	0.01	0.00	0.29
9.00	0.60	0.02	0.00	0.51
9.50	0.67	0.04	0.00	0.80
10.00	0.74	0.06	0.00	1.16
10.50	0.84	0.09	0.00	1.73
11.00	0.96	0.14	0.00	2.67
11.50	1.16	0.23	0.00	4.50
12.00	2.72	1.29	0.00	**32.80**
12.50	3.01	1.53	0.00	**33.07**
13.00	3.17	1.65	0.00	29.32
13.50	3.28	1.75	0.00	25.46
14.00	3.36	1.82	0.00	21.89
14.50	3.43	1.88	0.00	18.78
15.00	3.50	1.94	0.00	16.20
15.50	3.56	1.99	0.00	14.01
16.00	3.61	2.03	0.00	12.15
16.50	3.65	2.07	0.00	10.57
17.00	3.70	2.11	0.00	9.29
17.50	3.74	2.14	0.00	8.22
18.00	3.78	2.17	0.00	7.33
18.50	3.81	2.21	0.00	6.58
19.00	3.84	2.23	0.00	5.93
19.50	3.88	2.26	0.00	5.37
20.00	3.90	2.29	0.00	4.86
20.50	3.93	2.31	0.00	4.43
21.00	3.96	2.33	0.00	4.09
21.50	3.98	2.35	0.00	3.80
22.00	4.01	2.38	0.00	3.57
22.50	4.03	2.40	0.00	3.38
23.00	4.05	2.42	0.00	3.22
23.50	4.08	2.44	0.00	3.08
24.00	**4.10**	**2.46**	0.00	2.96
24.50	4.10	2.46	0.00	2.33
25.00	4.10	2.46	0.00	1.82
25.50	4.10	2.46	0.00	1.42
26.00	4.10	2.46	0.00	1.11
26.50	4.10	2.46	0.00	0.87
27.00	4.10	2.46	0.00	0.68
27.50	4.10	2.46	0.00	0.53
28.00	4.10	2.46	0.00	0.41
28.50	4.10	2.46	0.00	0.32
29.00	4.10	2.46	0.00	0.25
29.50	4.10	2.46	0.00	0.20
30.00	4.10	2.46	0.00	0.15

Summary for Subcatchment 6S: Pre-Development (Red)

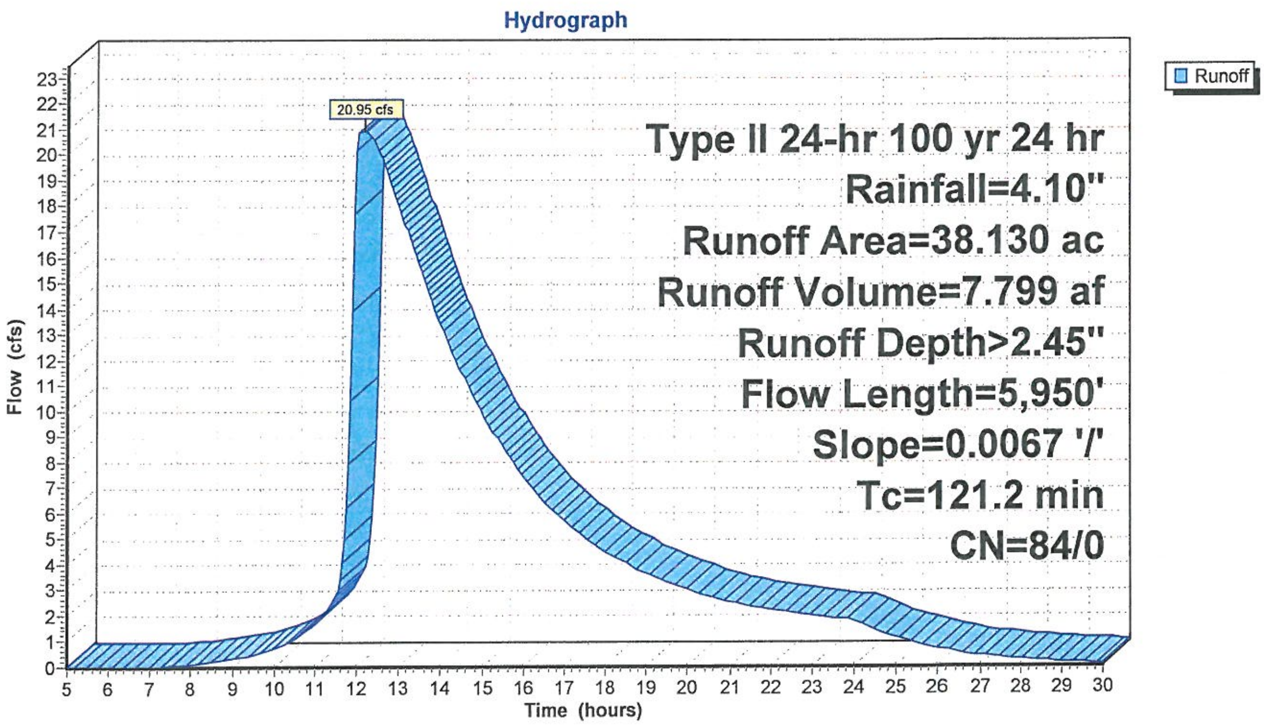
Runoff = 20.95 cfs @ 12.19 hrs, Volume= 7.799 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
38.130	84	Desert shrub range, Good, HSG D
38.130	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 6S: Pre-Development (Red)



Hydrograph for Subcatchment 6S: Pre-Development (Red)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.00
7.50	0.45	0.00	0.00	0.04
8.00	0.49	0.01	0.00	0.09
8.50	0.54	0.01	0.00	0.18
9.00	0.60	0.02	0.00	0.32
9.50	0.67	0.04	0.00	0.49
10.00	0.74	0.06	0.00	0.71
10.50	0.84	0.09	0.00	1.06
11.00	0.96	0.14	0.00	1.64
11.50	1.16	0.23	0.00	2.76
12.00	2.72	1.29	0.00	**20.14**
12.50	3.01	1.53	0.00	**20.30**
13.00	3.17	1.65	0.00	18.00
13.50	3.28	1.75	0.00	15.63
14.00	3.36	1.82	0.00	13.44
14.50	3.43	1.88	0.00	11.53
15.00	3.50	1.94	0.00	9.94
15.50	3.56	1.99	0.00	8.60
16.00	3.61	2.03	0.00	7.46
16.50	3.65	2.07	0.00	6.49
17.00	3.70	2.11	0.00	5.70
17.50	3.74	2.14	0.00	5.05
18.00	3.78	2.17	0.00	4.50
18.50	3.81	2.21	0.00	4.04
19.00	3.84	2.23	0.00	3.64
19.50	3.88	2.26	0.00	3.29
20.00	3.90	2.29	0.00	2.99
20.50	3.93	2.31	0.00	2.72
21.00	3.96	2.33	0.00	2.51
21.50	3.98	2.35	0.00	2.33
22.00	4.01	2.38	0.00	2.19
22.50	4.03	2.40	0.00	2.07
23.00	4.05	2.42	0.00	1.97
23.50	4.08	2.44	0.00	1.89
24.00	**4.10**	**2.46**	0.00	1.82
24.50	4.10	2.46	0.00	1.43
25.00	4.10	2.46	0.00	1.12
25.50	4.10	2.46	0.00	0.87
26.00	4.10	2.46	0.00	0.68
26.50	4.10	2.46	0.00	0.53
27.00	4.10	2.46	0.00	0.42
27.50	4.10	2.46	0.00	0.32
28.00	4.10	2.46	0.00	0.25
28.50	4.10	2.46	0.00	0.20
29.00	4.10	2.46	0.00	0.15
29.50	4.10	2.46	0.00	0.12
30.00	4.10	2.46	0.00	0.09

Summary for Subcatchment 7S: Pre-Development (Lavendar)

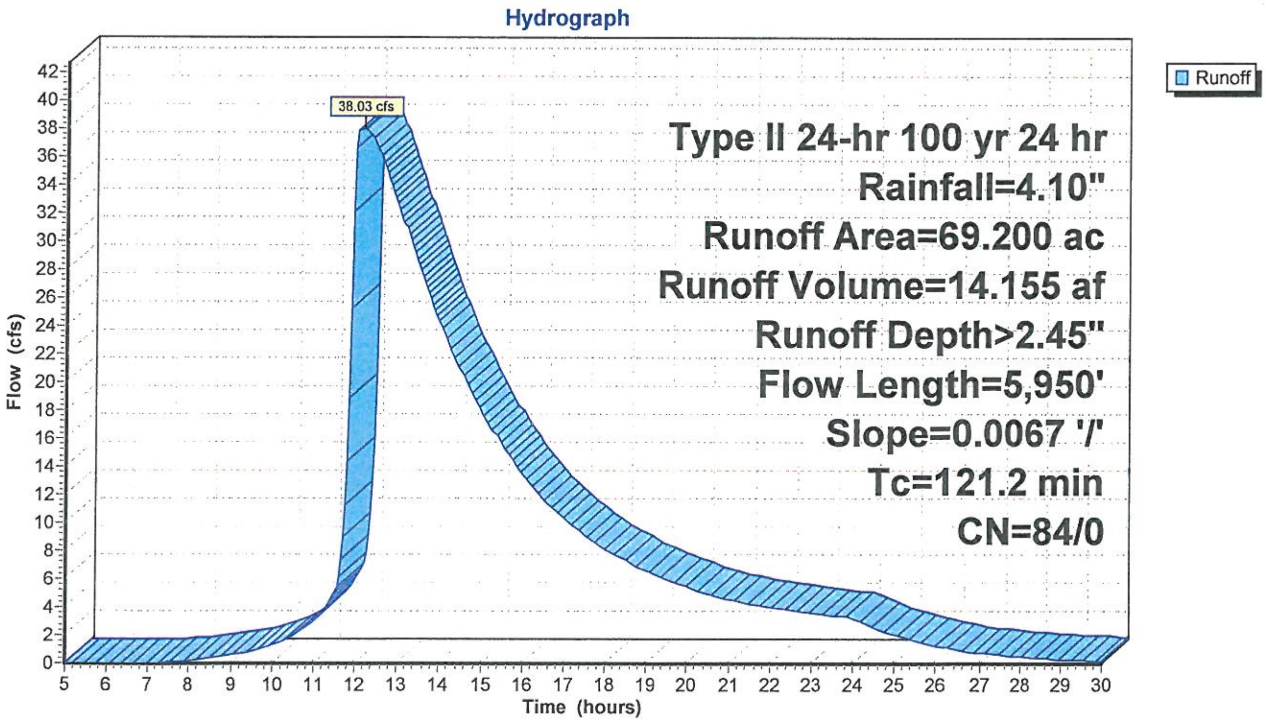
Runoff = 38.03 cfs @ 12.19 hrs, Volume= 14.155 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
69.200	84	Desert shrub range, Good, HSG D
69.200	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 7S: Pre-Development (Lavendar)



Hydrograph for Subcatchment 7S: Pre-Development (Lavendar)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.01
7.50	0.45	0.00	0.00	0.07
8.00	0.49	0.01	0.00	0.17
8.50	0.54	0.01	0.00	0.33
9.00	0.60	0.02	0.00	0.57
9.50	0.67	0.04	0.00	0.89
10.00	0.74	0.06	0.00	1.30
10.50	0.84	0.09	0.00	1.93
11.00	0.96	0.14	0.00	2.97
11.50	1.16	0.23	0.00	5.02
12.00	2.72	1.29	0.00	**36.55**
12.50	3.01	1.53	0.00	**36.84**
13.00	3.17	1.65	0.00	32.66
13.50	3.28	1.75	0.00	28.37
14.00	3.36	1.82	0.00	24.39
14.50	3.43	1.88	0.00	20.93
15.00	3.50	1.94	0.00	18.04
15.50	3.56	1.99	0.00	15.61
16.00	3.61	2.03	0.00	13.53
16.50	3.65	2.07	0.00	11.78
17.00	3.70	2.11	0.00	10.35
17.50	3.74	2.14	0.00	9.16
18.00	3.78	2.17	0.00	8.17
18.50	3.81	2.21	0.00	7.33
19.00	3.84	2.23	0.00	6.61
19.50	3.88	2.26	0.00	5.98
20.00	3.90	2.29	0.00	5.42
20.50	3.93	2.31	0.00	4.94
21.00	3.96	2.33	0.00	4.55
21.50	3.98	2.35	0.00	4.24
22.00	4.01	2.38	0.00	3.98
22.50	4.03	2.40	0.00	3.76
23.00	4.05	2.42	0.00	3.58
23.50	4.08	2.44	0.00	3.43
24.00	**4.10**	**2.46**	0.00	3.29
24.50	4.10	2.46	0.00	2.60
25.00	4.10	2.46	0.00	2.03
25.50	4.10	2.46	0.00	1.58
26.00	4.10	2.46	0.00	1.24
26.50	4.10	2.46	0.00	0.97
27.00	4.10	2.46	0.00	0.75
27.50	4.10	2.46	0.00	0.59
28.00	4.10	2.46	0.00	0.46
28.50	4.10	2.46	0.00	0.36
29.00	4.10	2.46	0.00	0.28
29.50	4.10	2.46	0.00	0.22
30.00	4.10	2.46	0.00	0.17

Summary for Subcatchment 3S: Pre-Development (Actual)

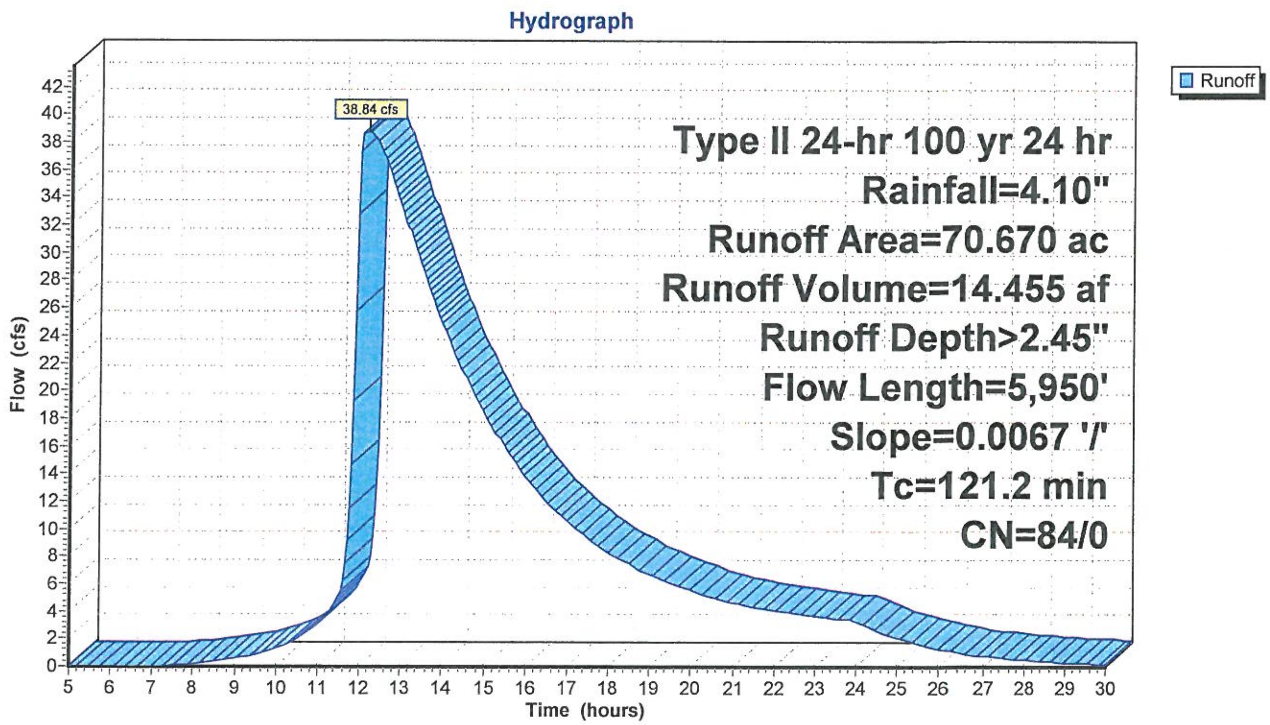
Runoff = 38.84 cfs @ 12.19 hrs, Volume= 14.455 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
70.670	84	Desert shrub range, Good, HSG D
70.670	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 3S: Pre-Development (Actual)



Hydrograph for Subcatchment 3S: Pre-Development (Actual)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.01
7.50	0.45	0.00	0.00	0.07
8.00	0.49	0.01	0.00	0.17
8.50	0.54	0.01	0.00	0.33
9.00	0.60	0.02	0.00	0.58
9.50	0.67	0.04	0.00	0.91
10.00	0.74	0.06	0.00	1.32
10.50	0.84	0.09	0.00	1.97
11.00	0.96	0.14	0.00	3.03
11.50	1.16	0.23	0.00	5.12
12.00	2.72	1.29	0.00	**37.32**
12.50	3.01	1.53	0.00	**37.63**
13.00	3.17	1.65	0.00	33.36
13.50	3.28	1.75	0.00	28.97
14.00	3.36	1.82	0.00	24.91
14.50	3.43	1.88	0.00	21.37
15.00	3.50	1.94	0.00	18.43
15.50	3.56	1.99	0.00	15.95
16.00	3.61	2.03	0.00	13.82
16.50	3.65	2.07	0.00	12.03
17.00	3.70	2.11	0.00	10.57
17.50	3.74	2.14	0.00	9.36
18.00	3.78	2.17	0.00	8.34
18.50	3.81	2.21	0.00	7.49
19.00	3.84	2.23	0.00	6.75
19.50	3.88	2.26	0.00	6.10
20.00	3.90	2.29	0.00	5.53
20.50	3.93	2.31	0.00	5.04
21.00	3.96	2.33	0.00	4.65
21.50	3.98	2.35	0.00	4.33
22.00	4.01	2.38	0.00	4.06
22.50	4.03	2.40	0.00	3.84
23.00	4.05	2.42	0.00	3.66
23.50	4.08	2.44	0.00	3.50
24.00	**4.10**	**2.46**	0.00	3.36
24.50	4.10	2.46	0.00	2.65
25.00	4.10	2.46	0.00	2.07
25.50	4.10	2.46	0.00	1.62
26.00	4.10	2.46	0.00	1.26
26.50	4.10	2.46	0.00	0.99
27.00	4.10	2.46	0.00	0.77
27.50	4.10	2.46	0.00	0.60
28.00	4.10	2.46	0.00	0.47
28.50	4.10	2.46	0.00	0.37
29.00	4.10	2.46	0.00	0.29
29.50	4.10	2.46	0.00	0.22
30.00	4.10	2.46	0.00	0.17

Summary for Subcatchment 8S: Pre-Development (Yellow)

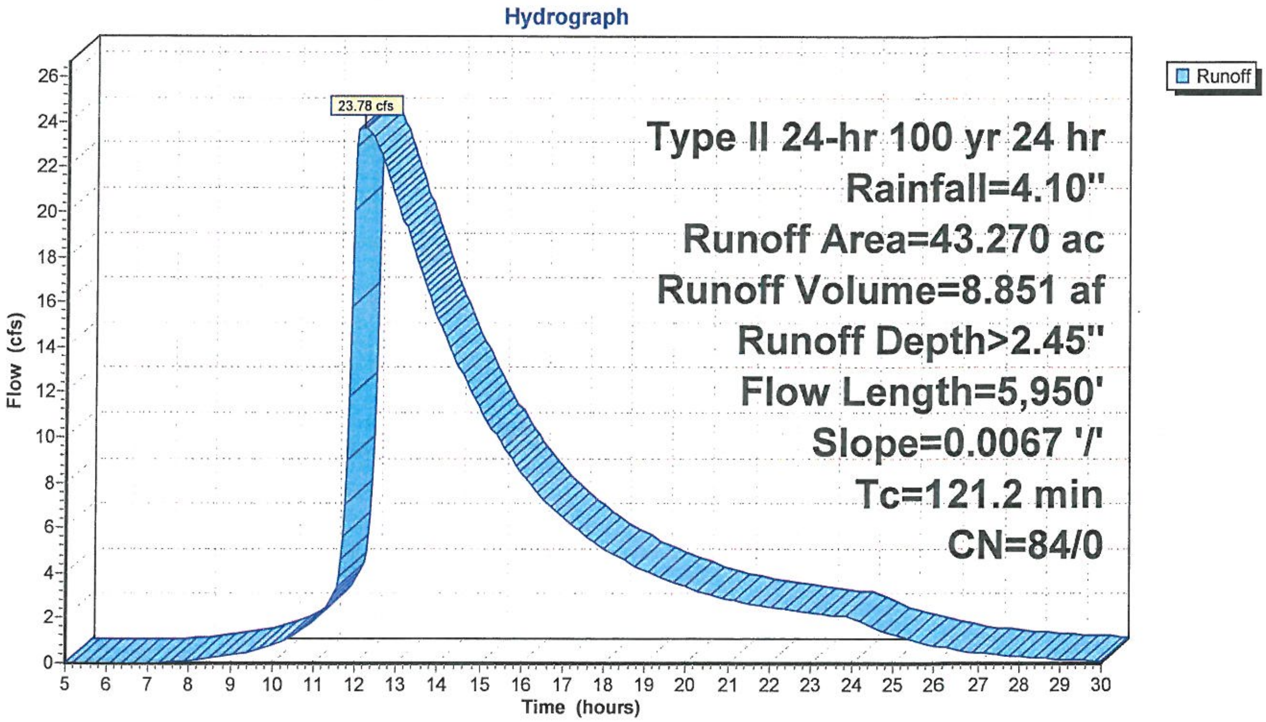
Runoff = 23.78 cfs @ 12.19 hrs, Volume= 8.851 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
43.270	84	Desert shrub range, Good, HSG D
43.270	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 8S: Pre-Development (Yellow)



Hydrograph for Subcatchment 8S: Pre-Development (Yellow)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.01
7.50	0.45	0.00	0.00	0.04
8.00	0.49	0.01	0.00	0.10
8.50	0.54	0.01	0.00	0.20
9.00	0.60	0.02	0.00	0.36
9.50	0.67	0.04	0.00	0.56
10.00	0.74	0.06	0.00	0.81
10.50	0.84	0.09	0.00	1.21
11.00	0.96	0.14	0.00	1.86
11.50	1.16	0.23	0.00	3.14
12.00	2.72	1.29	0.00	**22.85**
12.50	3.01	1.53	0.00	**23.04**
13.00	3.17	1.65	0.00	20.42
13.50	3.28	1.75	0.00	17.74
14.00	3.36	1.82	0.00	15.25
14.50	3.43	1.88	0.00	13.09
15.00	3.50	1.94	0.00	11.28
15.50	3.56	1.99	0.00	9.76
16.00	3.61	2.03	0.00	8.46
16.50	3.65	2.07	0.00	7.37
17.00	3.70	2.11	0.00	6.47
17.50	3.74	2.14	0.00	5.73
18.00	3.78	2.17	0.00	5.11
18.50	3.81	2.21	0.00	4.58
19.00	3.84	2.23	0.00	4.13
19.50	3.88	2.26	0.00	3.74
20.00	3.90	2.29	0.00	3.39
20.50	3.93	2.31	0.00	3.09
21.00	3.96	2.33	0.00	2.85
21.50	3.98	2.35	0.00	2.65
22.00	4.01	2.38	0.00	2.49
22.50	4.03	2.40	0.00	2.35
23.00	4.05	2.42	0.00	2.24
23.50	4.08	2.44	0.00	2.14
24.00	**4.10**	**2.46**	0.00	2.06
24.50	4.10	2.46	0.00	1.63
25.00	4.10	2.46	0.00	1.27
25.50	4.10	2.46	0.00	0.99
26.00	4.10	2.46	0.00	0.77
26.50	4.10	2.46	0.00	0.60
27.00	4.10	2.46	0.00	0.47
27.50	4.10	2.46	0.00	0.37
28.00	4.10	2.46	0.00	0.29
28.50	4.10	2.46	0.00	0.22
29.00	4.10	2.46	0.00	0.18
29.50	4.10	2.46	0.00	0.14
30.00	4.10	2.46	0.00	0.11

Summary for Subcatchment 9S: Pre-Development (Green)

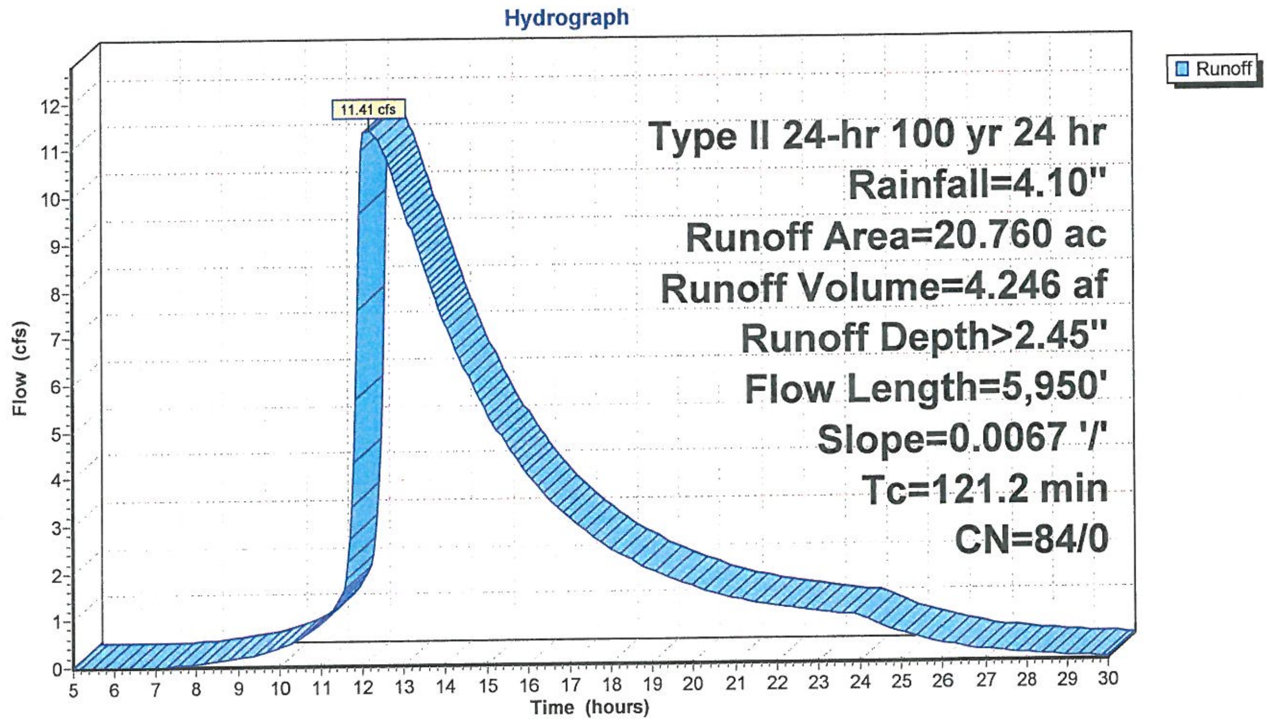
Runoff = 11.41 cfs @ 12.19 hrs, Volume= 4.246 af, Depth> 2.45"

Runoff by SBUH method, Split Pervious/Imperv., Time Span= 5.00-30.00 hrs, dt= 0.05 hrs
Type II 24-hr 100 yr 24 hr Rainfall=4.10"

Area (ac)	CN	Description
20.760	84	Desert shrub range, Good, HSG D
20.760	84	Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
121.2	5,950	0.0067	0.82		**Shallow Concentrated Flow, Total Pre-developed Site** Nearly Bare & Untilled Kv= 10.0 fps

Subcatchment 9S: Pre-Development (Green)



Hydrograph for Subcatchment 9S: Pre-Development (Green)

Time (hours)	Precip. (inches)	Perv.Excess (inches)	Imp.Excess (inches)	Runoff (cfs)
5.00	0.26	0.00	**0.00**	0.00
5.50	0.29	0.00	0.00	0.00
6.00	0.33	0.00	0.00	0.00
6.50	0.37	0.00	0.00	0.00
7.00	0.41	0.00	0.00	0.00
7.50	0.45	0.00	0.00	0.02
8.00	0.49	0.01	0.00	0.05
8.50	0.54	0.01	0.00	0.10
9.00	0.60	0.02	0.00	0.17
9.50	0.67	0.04	0.00	0.27
10.00	0.74	0.06	0.00	0.39
10.50	0.84	0.09	0.00	0.58
11.00	0.96	0.14	0.00	0.89
11.50	1.16	0.23	0.00	1.50
12.00	2.72	1.29	0.00	**10.96**
12.50	3.01	1.53	0.00	**11.05**
13.00	3.17	1.65	0.00	9.80
13.50	3.28	1.75	0.00	8.51
14.00	3.36	1.82	0.00	7.32
14.50	3.43	1.88	0.00	6.28
15.00	3.50	1.94	0.00	5.41
15.50	3.56	1.99	0.00	4.68
16.00	3.61	2.03	0.00	4.06
16.50	3.65	2.07	0.00	3.53
17.00	3.70	2.11	0.00	3.10
17.50	3.74	2.14	0.00	2.75
18.00	3.78	2.17	0.00	2.45
18.50	3.81	2.21	0.00	2.20
19.00	3.84	2.23	0.00	1.98
19.50	3.88	2.26	0.00	1.79
20.00	3.90	2.29	0.00	1.63
20.50	3.93	2.31	0.00	1.48
21.00	3.96	2.33	0.00	1.37
21.50	3.98	2.35	0.00	1.27
22.00	4.01	2.38	0.00	1.19
22.50	4.03	2.40	0.00	1.13
23.00	4.05	2.42	0.00	1.07
23.50	4.08	2.44	0.00	1.03
24.00	**4.10**	**2.46**	0.00	0.99
24.50	4.10	2.46	0.00	0.78
25.00	4.10	2.46	0.00	0.61
25.50	4.10	2.46	0.00	0.48
26.00	4.10	2.46	0.00	0.37
26.50	4.10	2.46	0.00	0.29
27.00	4.10	2.46	0.00	0.23
27.50	4.10	2.46	0.00	0.18
28.00	4.10	2.46	0.00	0.14
28.50	4.10	2.46	0.00	0.11
29.00	4.10	2.46	0.00	0.08
29.50	4.10	2.46	0.00	0.07
30.00	4.10	2.46	0.00	0.05

Attachment D: Site Soil Information

Dominant vegetation on the Huachuca soil:
• In the potential and present plant communities—45 percent canopy cover of alligator juniper, Mexican pinyon, mountain mahogany, silverleaf oak, ponderosa pine, Apache pine, and Arizona white oak with an understory of pinyon ricegrass, sideoats grama, bullgrass, silktassel, blue muhly, and agave

Dominant vegetation on the Hogris soil:
• In the potential and present plant communities—35 percent canopy cover of Arizona white oak, Emory oak, alligator juniper, and Mexican pinyon with an understory of bullgrass, plains lovegrass, beggartick threeawn, sideoats grama, Texas bluestem, wooly bunchgrass, hairy grama, sedge, yucca, sacahuista, and sotol

Special Management Concerns

• This unit responds well to managed, natural and prescribed fires.
• These soils have a moderate or severe hazard of water erosion because of the slope; therefore, special consideration should be given to water management.
• Steep slopes cause management problems.

Interpretive Groups

Land capability classification:
Slopes of 15 to 30 percent—VIs nonirrigated
Slopes of 30 to 70 percent—VIe nonirrigated
Ecological site:
Far and Huachuca—Mountains (PIPO), 25+-inch precipitation zone, 041XA128AZ
Hogris—Loamy Hills (QUAR, QUEM), 20- to 23-inch precipitation zone, 041A124AZ
Major land resource area: 41—Southeastern Arizona Basin and Range
Land resource unit: 41-1AZ—Mexican Oak-Pine Woodland and Oak Savannah

65—Forrest clay loam, 1 to 3 percent slopes

Setting

Landform: fan terraces
Slope range: 1 to 3 percent
Elevation: 4,000 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days

Composition

Forrest and similar soils: 85 percent
Contrasting inclusions: 15 percent

Typical Profile

0 to 6 inches—brown clay loam
6 to 28 inches—reddish brown and light reddish brown clay
28 to 37 inches—pink, calcareous clay
37 to 60 inches—pink, calcareous clay loam

Soil Properties and Qualities

Parent material: mixed fan alluvium
Depth class: very deep
Drainage class: well drained
Permeability: slow
Available water capacity: high or very high
Potential rooting depth: 60 inches or more
Runoff rate: low
Hazard of erosion: by water—slight; by wind—moderate
Shrink-swell potential: high
Depth to a calcic horizon: 20 to 40 inches
Calcium carbonate equivalent: 15 to 30 percent in the lower part of the soil
Corrosivity: steel—high; concrete—moderate

Inclusions

Contrasting inclusions:
• McAllister, Courtland, McNeal, Kahn, and Riveroad soils, which have 18 to 35 percent clay
• Sasabe soils, which do not have accumulations of calcium carbonate
• Luckyhills, Combate, Comoro, Diaspar, Mallet, Stronghold, and Ubik soils, which have less than 18 percent clay
• Libby, Gulch, and Zapolote soils, which have petronodes and/or gypsum
• Guest and Bonita soils, which do not have an argillic horizon
• Blakeney and Buntline soils, which are very shallow or shallow to a hardpan
• Bodecker, Altar, and Nolam soils, which have more than 35 percent rock fragments
• Durazo soils, which are sandy and have a very high hazard of wind erosion

Similar inclusions:
• Forrest soils that have a surface layer of sandy loam
• Forrest soils that have salts and sodium in the lower part and are adjacent to Whitewater Draw

Use and Management

Major current uses: livestock grazing, irrigated cropland, and wildlife habitat

Soil-related factors: high shrink-swell potential, hazard of wind erosion, slow permeability

Dominant vegetation:
- In the potential plant community—blue grama, vine mesquite, sideoats grama, cane beardgrass, tobosa, giant sacaton, yucca, creeping muhly
- In the present plant community—blue grama, vine mesquite, Lehmann lovegrass, annual forbs, burroweed, broom snakeweed, yucca

Special Management Concerns

- Overuse results in a loss of diversity in the plant community.
- The high content of clay in the soil restricts water infiltration and permeability.
- The high shrink-swell potential should be considered when foundations, concrete structures, and paved areas are designed and constructed.
- This soil has a moderate hazard of wind erosion. When vegetation is removed, care should be taken to prevent excessive dust and soil loss.

Interpretive Groups

Land capability classification: IIIs irrigated and VIs nonirrigated
Ecological site: Loamy Bottom, Swales, 12- to 16-inch precipitation zone, 041XC311AZ
Major land resource area: 41—Southeastern Arizona Basin and Range
Land resource unit: 41-3AZ—Southern Arizona Semidesert Grassland

66—Forrest clay loam, saline-sodic, 1 to 3 percent slopes

Setting

Landform: fan terraces
Slope range: 1 to 3 percent
Elevation: 4,000 to 4,600 feet
Mean annual precipitation: 12 to 16 inches
Mean annual air temperature: 60 to 67 degrees F
Frost-free period: 180 to 230 days

Composition

Forrest and similar soils: 85 percent
Contrasting inclusions: 15 percent

Typical Profile

0 to 6 inches—brown clay loam
6 to 28 inches—reddish brown and light reddish brown, saline-sodic clay
28 to 37 inches—pink, saline-sodic, calcareous clay
37 to 60 inches—pink, saline-sodic, calcareous clay loam

Soil Properties and Qualities

Parent material: mixed fan alluvium
Depth class: very deep
Drainage class: well drained
Permeability: slow
Available water capacity: high
Potential rooting depth: 60 inches or more
Runoff rate: low
Hazard of erosion: by water—slight; by wind—moderate
Shrink-swell potential: high
Depth to a calcic horizon: 20 to 40 inches
Calcium carbonate equivalent: 15 to 30 percent in the lower part of the soil
Content of gypsum: 0 to 4 percent
Salinity: slight to strong
Sodicity: moderate or strong
Corrosivity: steel—high; concrete—high

Inclusions

Contrasting inclusions:
- McAllister, Courtland, McNeal, Kahn, and Riveroad soils, which have 18 to 35 percent clay
- Sasabe soils, which do not have accumulations of calcium carbonate
- Luckyhills, Combate, Comoro, Diaspar, Mallet, Stronghold, and Ubik soils, which have less than 18 percent clay
- Libby, Gulch, and Zapolote soils, which have petronodes and/or gypsum
- Guest and Bonita soils, which do not have an argillic horizon
- Blakeney and Buntline soils, which are very shallow or shallow to a hardpan
- Bodecker, Altar, and Nolam soils, which have more than 35 percent rock fragments
- Durazo soils, which are sandy and have a very high hazard of wind erosion

Similar inclusions:
- Forrest soils that have a surface layer of sandy loam

Use and Management

Major current uses: livestock grazing, irrigated cropland, and wildlife habitat

Soil-related factors: high shrink-swell potential, hazard of wind erosion, slow permeability, excess salts, sodium, and gypsum

Dominant vegetation:
- In the potential plant community—blue grama, vine

Hydrologic Soil Group

Hydrologic Soil Group— Summary by Map Unit — Cochise County, Arizona, Douglas-Tombstone Part (AZ671)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
65	Forrest clay loam, 1 to 3 percent slopes	C	182.9	54.6%
109	McNeal gravelly sandy loam, 1 to 3 percent slopes	B	22.0	6.6%
120	Perilla-Durazo complex, 0 to 3 percent slopes	B	128.3	38.3%
145	Ubik loam, 1 to 3 percent slopes	B	1.8	0.5%
Totals for Area of Interest			**334.9**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Aggregation is the process by which a set of component attribute values is reduced to a single value that represents the map unit as a whole.

A map unit is typically composed of one or more "components". A component is either some type of soil or some nonsoil entity, e.g., rock outcrop. For the attribute being aggregated, the first step of the aggregation process is to derive one attribute value for each of a map unit's components. From this set of component attributes, the next step of the aggregation process derives a single value that represents the map unit as a whole. Once a single value for each map unit is derived, a thematic map for soil map units can be rendered. Aggregation must be done because, on any soil map, map units are delineated but components are not.

For each of a map unit's components, a corresponding percent composition is recorded. A percent composition of 60 indicates that the corresponding component typically makes up approximately 60% of the map unit. Percent composition is a critical factor in some, but not all, aggregation methods.

The aggregation method "Dominant Condition" first groups like attribute values for the components in a map unit. For each group, percent composition is set to the sum of the percent composition of all components participating in that group. These groups now represent "conditions" rather than components. The attribute value associated with the group with the highest cumulative percent composition is returned. If more than one group shares the highest cumulative percent composition, the corresponding "tie-break" rule determines which value should be returned. The "tie-break" rule indicates whether the lower or higher group value should be returned in the case of a percent composition tie.

The result returned by this aggregation method represents the dominant condition throughout the map unit only when no tie has occurred.

Component Percent Cutoff: None Specified

Components whose percent composition is below the cutoff value will not be considered. If no cutoff value is specified, all components in the database will be considered. The data for some contrasting soils of minor extent may not be in the database, and therefore are not considered.

Tie-break Rule: Higher

The tie-break rule indicates which value should be selected from a set of multiple candidate values, or which value should be selected in the event of a percent composition tie.

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Units

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features
- Gully
- Short Steep Slope
- Other

Political Features
- Cities

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:4,830 if printed on B size (11" × 17") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Cochise County, Arizona, Douglas-Tombstone Part
Survey Area Data: Version 8, Sep 9, 2008

Date(s) aerial images were photographed: 6/30/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Cochise County, Arizona, Douglas-Tombstone Part (AZ671)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
65	Forrest clay loam, 1 to 3 percent slopes	182.9	54.6%
109	McNeal gravelly sandy loam, 1 to 3 percent slopes	22.0	6.6%
120	Perilla-Durazo complex, 0 to 3 percent slopes	128.3	38.3%
145	Ubik loam, 1 to 3 percent slopes	1.8	0.5%
Totals for Area of Interest		**334.9**	**100.0%**

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Soil Ratings

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Political Features

- Cities

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:4,830 if printed on B size (11" × 17") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 12N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

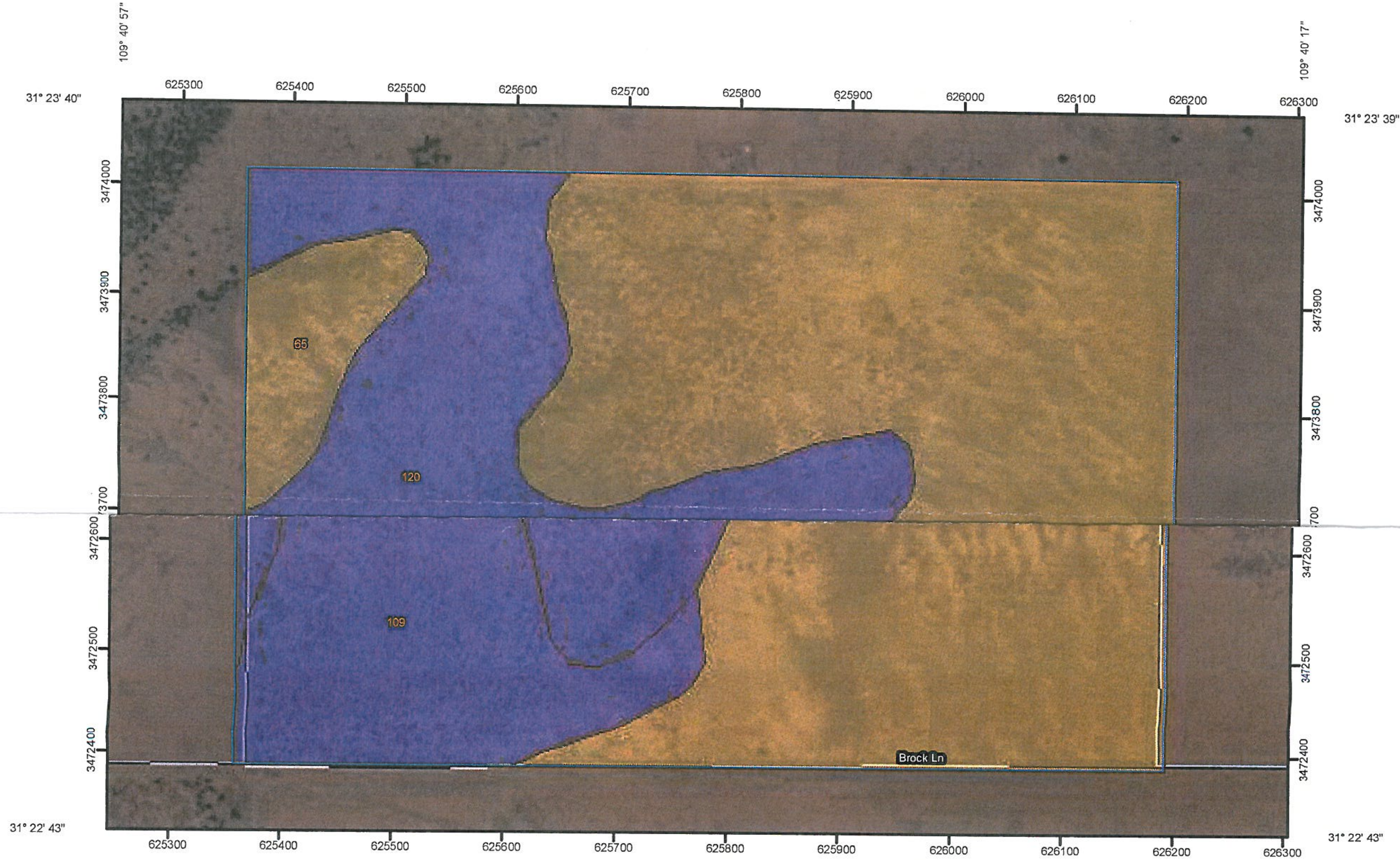
Soil Survey Area: Cochise County, Arizona, Douglas-Tombstone Part
Survey Area Data: Version 8, Sep 9, 2008

Date(s) aerial images were photographed: 6/30/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Soil Map—Cochise County, Arizona, Douglas-Tombstone Part

Hydrologic Soil Group—Cochise County, Arizona, Douglas-Tombstone Part



Map Scale: 1:4,830 if printed on B size (11" x 17") sheet.