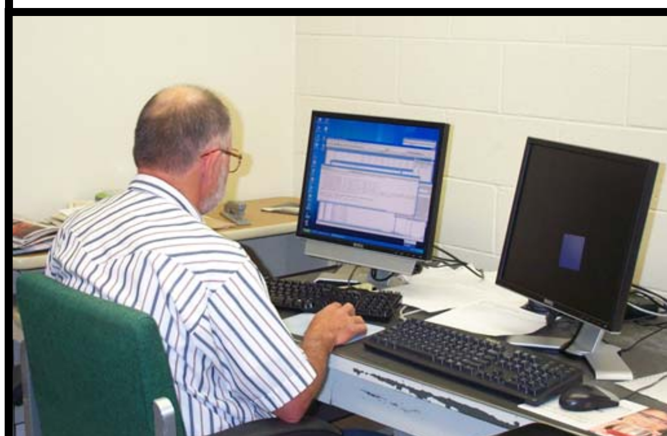
INTRODUCTION

- Model development at Temple
  - A long history (1937-present)
  - Many scientists participating in:
    - Data collection
    - Component construction
    - Structural design
    - Validation
    - Application

Then

Now

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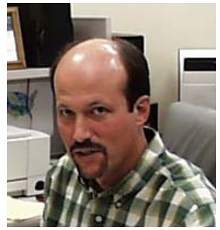
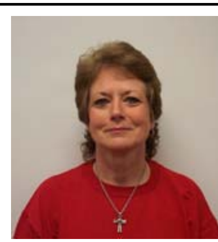
TEMPLE MODELING GROUP

 **Jimmy Williams** Systems modeling & EPIC/APEX dev. (1965)	 **Jeff Arnold** SWAT developer (1983)	 **Jim Kiniry** ALMANAC developer (1980)	 **Paul Dyke** Agricultural Models (1987)
 **Cole Rossi** SWAT developer/support (2004)	 **Raghavan Srinivasan** GIS Specialist & SWAT interface developer (1992)	 **Armen Kemanian** Cropping systems modeling (EPIC/APEX) (2006)	 **Ken Potter** Soil Scientist (1989)
 **Tim Dybala** NRCS Civil Engineer (WRAT Team) (1992)	 **Lee Norfleet** NRCS Soil Scientist (2004)	 **Jay Atwood** NRCS Economist (1991)	 **Susan Wang** Simulation Modeling (APEX/EPIC) (2004)

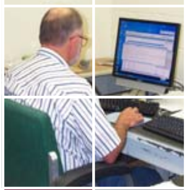
TEMPLE MODELING GROUP

 **Mike White** SWAT development/support (2008)	 **Kannan Narayanan** Simulation Modeling (2004)	 **Santhi Chinnasamy** Hydrologic modeling/SWAT (1998)	 **Mauro Diluzio** Hydrology/GIS modeling (1997)
 **Pushpa Tuppad** Hydrology/GIS modeling (2006)	 **Norman Meki** Modeling (EPIC) (2007)	 **Carl Amonett** NRCS Soil Conservationist (WRAT Team) ()	 **Todd Marek** NRCS Civil Engineer (WRAT Team) (2005)
 **Nancy Sammons** SWAT User support (1973)	 **Georgie Mitchell** SWAT User support (1977)	 **Evelyn Steglich** EPIC/APEX User support/training (1997)	 **Avery Meinardus** Programmer (1994)

TEMPLE MODELING GROUP

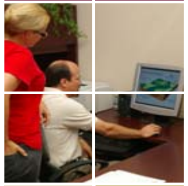
 **Larry Francis** Program Analyst (1996)	 **Bill Komar** Database administration (2007)	 **Paul Duckworth** GIS specialist (2003)	 **Melanie Magre** Interface manual editor (1996)
 **Theresa Pitts** Programmer (1998)	 **Shawn Quisenberry** Program analyst (2007)	 **Deborah Spanel** Biological Science Tech/ALMANAC (1985)	 **Jaehak Jeong** Hydrologic modeling (2008)

INTRODUCTION
TEMPLE MODELS



- ALMANAC, EPIC, APEX, SWAT
  - Operate on spatial scales ranging from individual fields to river basins
  - Daily time step
  - Continuously updated and improved as a result of user interaction and feedback

PARTICIPATION IN OTHER MODEL DEVELOPMENT

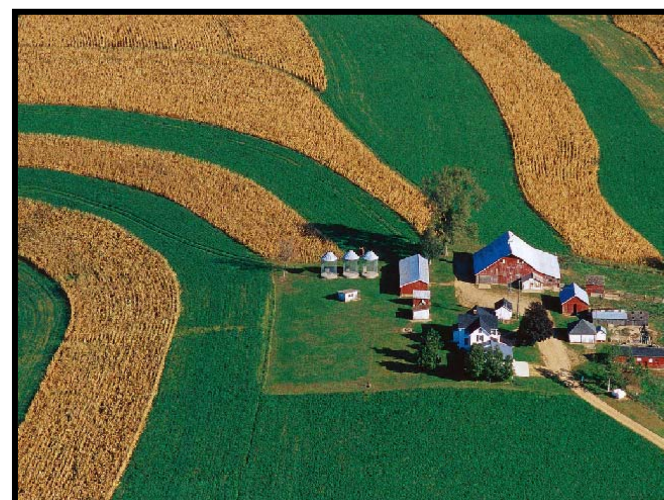


- GLEAMS
- SPUR
- WEPP
- WEPS
- NLEAP

APEX

AGRICULTURAL POLICY / ENVIRONMENTAL eXTENDER MODEL

- Whole farm/watershed scale
- Subarea component (EPIC)
- Routing (water, sediment, nutrients, pesticides)
- Groundwater & reservoir
- Feedlot dust distribution
- Daily time step
- Capable of simulating 100’s of years
- (2000)

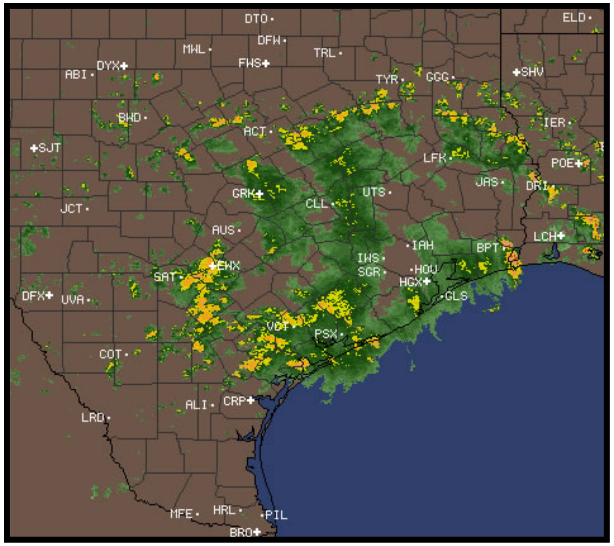


The EPIC MODEL

- Weather
- Hydrology
- Erosion (wind & water)
- Carbon
- Nutrients (N, P, & K)
- Pesticides
- Salinity
- Crop Growth
- Tillage
- Grazing
- Manure Management
- Economics

WEATHER

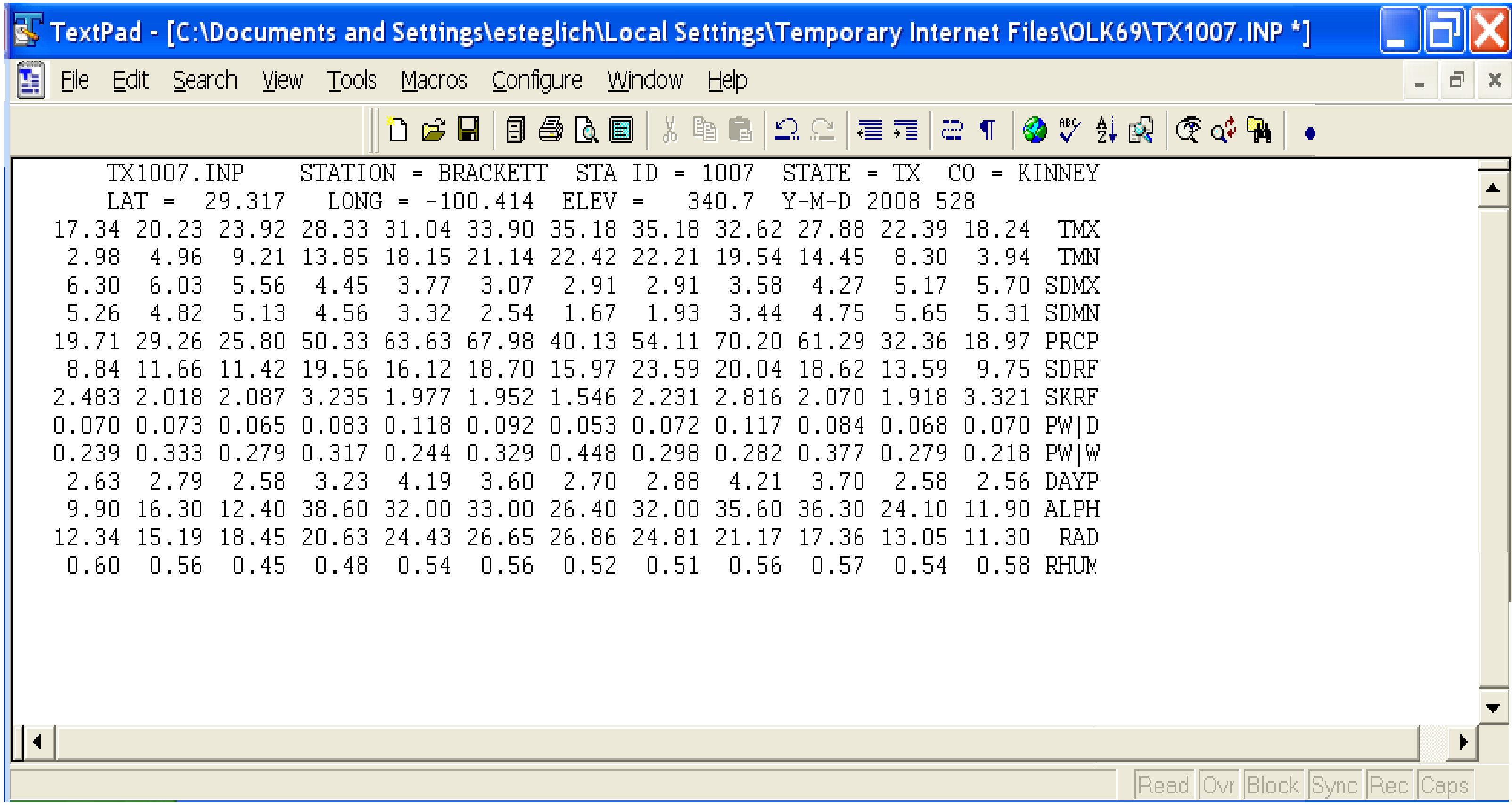
- Measured or Simulated
- Temperature (Max and Min)
- Precipitation
- Radiation
- Relative humidity
- Wind speed and direction



WEATHER SIMULATION

- WXGN
  - Stand alone weather generator built into EPIC
- WXPM
  - Stand alone program for computing monthly input statistics

WXPM WEATHER GENERATOR

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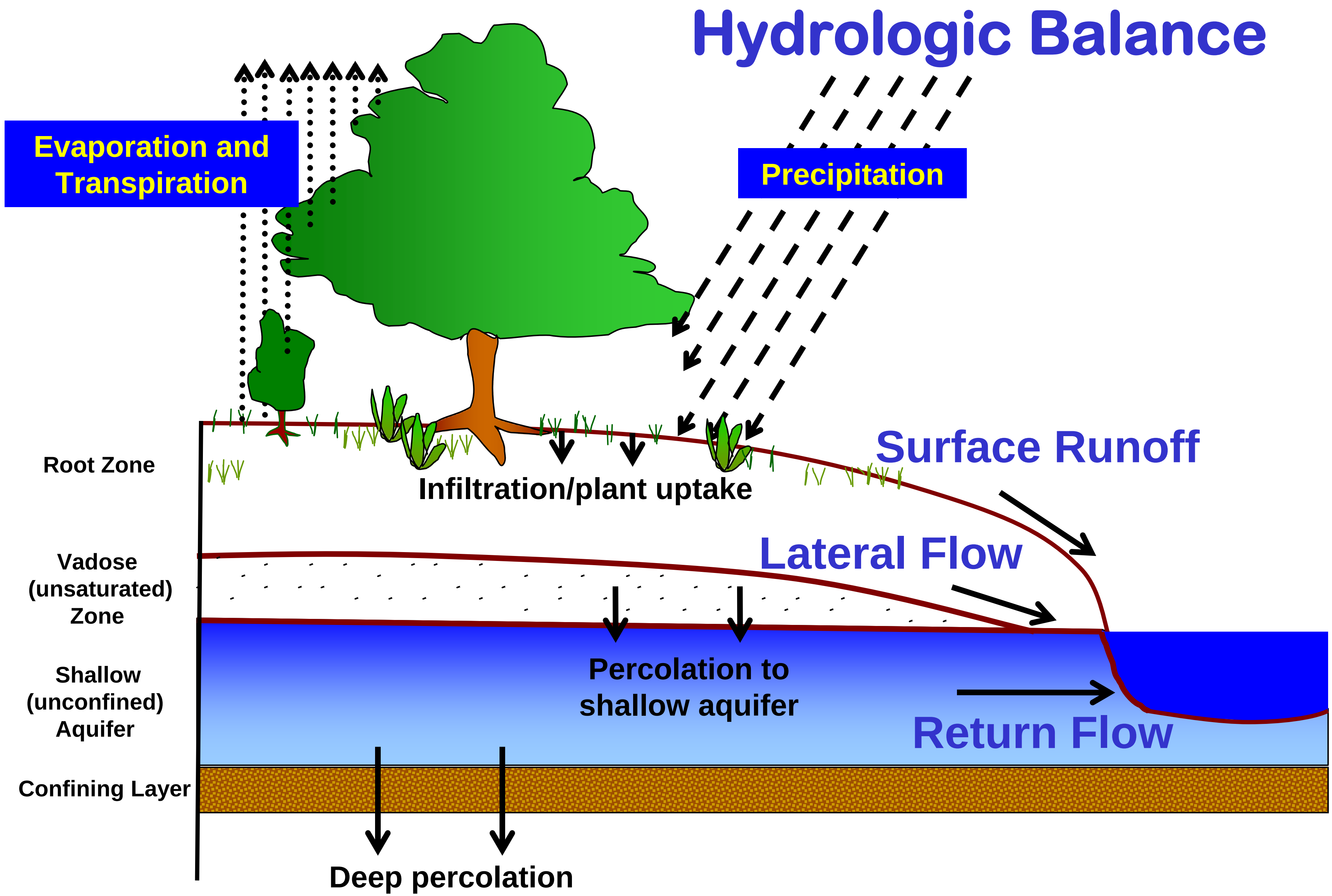
    LAT =  29.317   LONG = -100.414  ELEV =   340.7  Y-M-D 2008 528
17.34 20.23 23.92 28.33 31.04 33.90 35.18 35.18 32.62 27.88 22.39 18.24  TMX
 2.98  4.96  9.21 13.85 18.15 21.14 22.42 22.21 19.54 14.45  8.30  3.94  TMN
 6.30  6.03  5.56  4.45  3.77  3.07  2.91  2.91  3.58  4.27  5.17  5.70 SDMX
 5.26  4.82  5.13  4.56  3.32  2.54  1.67  1.93  3.44  4.75  5.65  5.31 SDMN
19.71 29.26 25.80 50.33 63.63 67.98 40.13 54.11 70.20 61.29 32.36 18.97 PRCP
 8.84 11.66 11.42 19.56 16.12 18.70 15.97 23.59 20.04 18.62 13.59  9.75 SDRF
2.483 2.018 2.087 3.235 1.977 1.952 1.546 2.231 2.816 2.070 1.918 3.321 SKRF
0.070 0.073 0.065 0.083 0.118 0.092 0.053 0.072 0.117 0.084 0.068 0.070 PW|D
0.239 0.333 0.279 0.317 0.244 0.329 0.448 0.298 0.282 0.377 0.279 0.218 PW|W
 2.63  2.79  2.58  3.23  4.19  3.60  2.70  2.88  4.21  3.70  2.58  2.56 DAYP
 9.90 16.30 12.40 38.60 32.00 33.00 26.40 32.00 35.60 36.30 24.10 11.90 ALPH
12.34 15.19 18.45 20.63 24.43 26.65 26.86 24.81 21.17 17.36 13.05 11.30  RAD
 0.60  0.56  0.45  0.48  0.54  0.56  0.52  0.51  0.56  0.57  0.54  0.58 RHUM
```

WEATHER SIMULATION

- MODAWTHC
  - Stand alone program for converting monthly precipitation to daily
    - Inputs (for each year of record)
      - Monthly maximum temperature
      - Monthly minimum temperature
      - Monthly precipitation
      - Average number of wet days per month
    - Outputs
      - Daily weather file
      - WPM1 file

EPIC WEATHER GENERATOR (WXGN)

- Precipitation
  - Rainfall
    - Occurrence
      - Generated random number compared with wet-dry probabilities
    - Amount
      - Generated from skewed normal distribution
      - Generated from modified exponential distribution

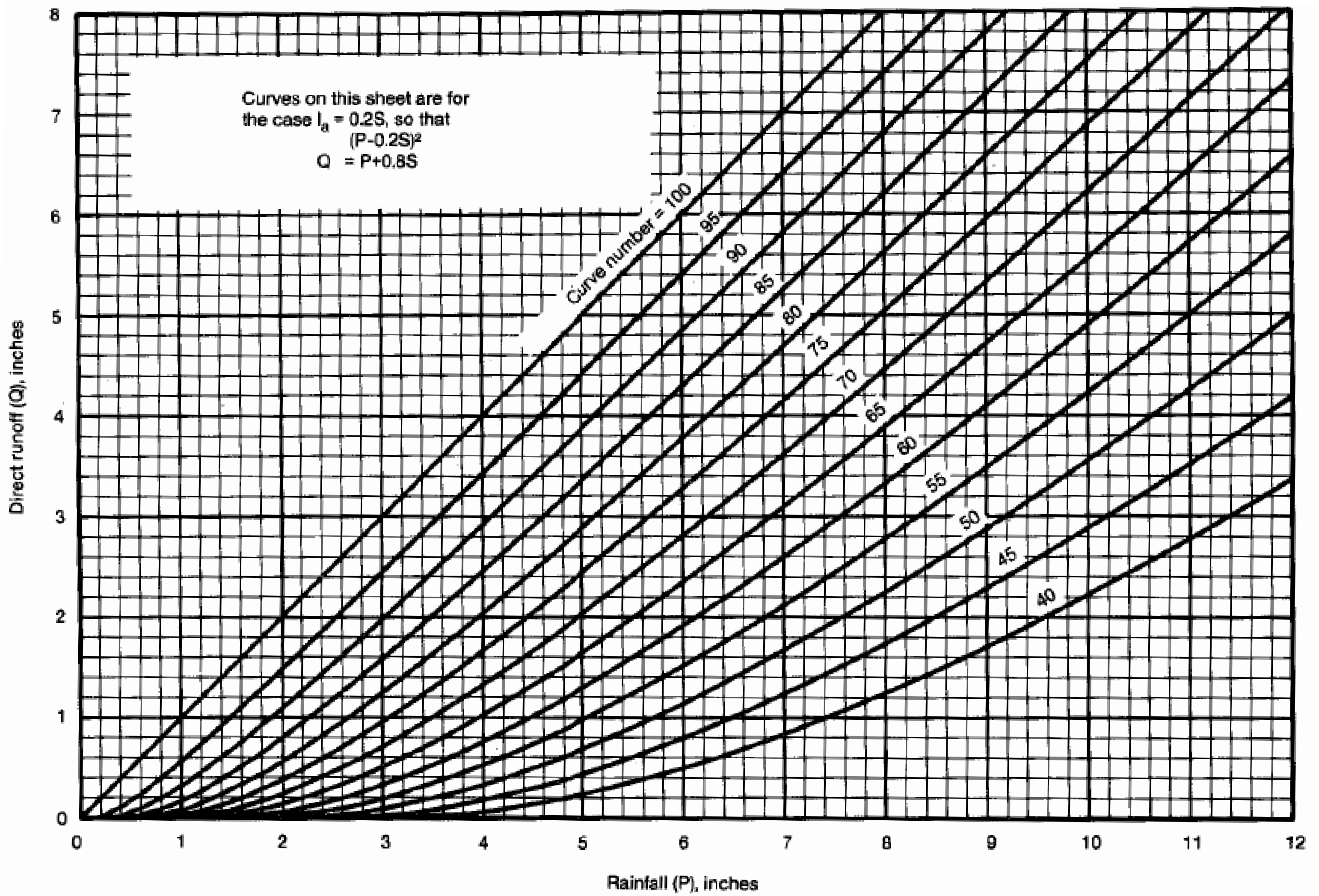


Hydrologic Balance
Evaporation and Transpiration
Precipitation
Root Zone
Infiltration/plant uptake
Surface Runoff
Lateral Flow
Vadose (unsaturated) Zone
Shallow (unconfined) Aquifer
Percolation to shallow aquifer
Return Flow
Confining Layer
Deep percolation

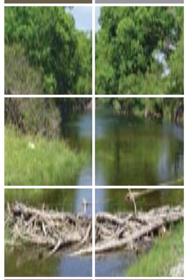
HYDROLOGY

- Surface Runoff
- Volume
  - –SCS curve number
  - –Green & Ampt
- Peak rate
  - –Modified rational
  - –SCS TR-55

HYDROLOGY



Curves on this sheet are for
the case I_a = 0.2S, so that
$Q = \frac{(P-0.2S)^2}{P+0.8S}$
Curve number = 100
95
90
85
80
75
70
65
60
55
50
45
40
Direct runoff (Q), inches
Rainfall (P), inches
0
1
2
3
4
5
6
7
8
9
10
11
12



Land use	Cover Treatment or practice	Hydrologic condition	Hydrologic soil group A	B	C	D	**Land Use Number**
Fallow	Straight row	----	77	86	91	94	1
Row crops	Straight row	Poor	72	81	88	91	2
"	"	Good	67	78	85	89	3
	Contoured	Poor	70	79	84	88	4
	" "	Good	65	75	82	86	5
	Contoured & terraced	Poor	66	74	80	82	6
	" "	Good	62	71	78	81	7
Small grain	Straight row	Poor	65	76	84	88	8
	" "	Good	63	75	83	87	9
	Contoured	Poor	63	74	82	85	10
	" "	Good	61	73	81	84	11
	Contoured & terraced	Poor	61	72	79	82	12
	" "	Good	59	70	78	81	13
Close-seeded legumes[1] or rotation meadow	Straight row	Poor	66	77	85	89	14
	" "	Good	58	72	81	85	15
	Contoured	Poor	64	75	83	85	16
	" "	Good	55	69	78	83	17
	Contoured & terraced	Poor	63	73	80	83	18
	" "	Good	51	67	76	80	19
Pasture or range		Poor	68	79	86	89	20
		Fair	49	69	79	84	21
		Good	39	61	74	80	22
	Contoured	Poor	47	67	81	88	23
	" "	Fair	25	59	75	83	24
	" "	Good	6	35	70	79	25
Meadow		Good	30	58	71	78	26
Woods		Poor	45	66	77	83	27
		Fair	36	60	73	79	28
		Good	25	55	70	77	29
Farmsteads		----	59	74	82	86	30
Roads (dirt)[2]		----	72	82	87	89	31
(hard surface)[2]		----	74	84	90	92	32
Sugarcane			39	61	74	80	33
Impervious (Pavement, urban area)	----		98	98	98	98	35

1 Close-drilled or broadcast.
2 Including right of way.

Taken from the National Engineering Handbook (U.S. Department of Agriculture, Soil Conservation Service 1972).

HYDROLOGY

Sub Surface Flow

- Root Zone
  - ➢ Lateral
    - ✓Flow to down stream subarea
    - ✓Quick return flow
    - ✓ Pipe flow
  - ➢ Percolation to shallow groundwater
- Ground Water
  - ➢ Water table Dynamics
  - ➢ Return Flow
  - ➢ Deep Percolation

HYDROLOGY

- Evapotranspiration
  - PET Equations
    - Penman
    - Penman-Montieth
    - Priestley-Taylor
    - Hargreaves
    - Baier-Robertson

EROSION

- Water
  - USLE
  - USLE modifications
    - ✓MUSLE
    - ✓Onstad-Foster
    - ✓RUSLE
- Wind
  - Manhattan, KS with Bagnolds energy equation

CARBON-NITROGEN TRANSFORMATIONS

EPIC/CENTURY

- Pools
  - Structural litter (1 year)
    - Has a fixed C/N ratio
  - Metabolic litter (<1 year)
    - Contains all the lignin from plant residues and roots
    - Made up of readily decomposable and water soluble organic matter
  - Biomass (<1 year)
    - Soil microbial biomass
  - Slow humus (5 years)
    - Soil organic matter which decomposes at rates intermediate to the microbial and passive humus components
  - Passive humus (200+ years)
    - Composed of old or stable soil organic matter

CARBON

Potential transformations

- Regulated by
  - Moisture
  - Temperature
  - Tillage/compaction
  - Oxygen
- Actual transformations
  - Regulated by
  - Nitrogen availability
  - Mineralization-Immobilization
- Losses
  - Respiration
  - Erosion
  - Runoff/leaching (soluble)

NUTRIENTS

- Nitrogen
  - –Surface runoff
    - soluble and adsorbed
  - – Subsurface flow
    - lateral and vertical
  - –Mineralization
  - –Immobilization
  - –Denitrification
  - –Volatilization
  - –Nitrification
  - –Crop uptake

NUTRIENTS

- Phosphorus
  - Surface runoff
    - soluble and adsorbed
  - Leaching
  - Mineralization
  - Immobilization
  - Adsorption-desorption
  - Crop uptake

PESTICIDE FATE GLEAMS

- Surface runoff
  - soluble and adsorbed
- Leaching
- Degradation
  - from foliage and soil
- Washoff from plants
  - rainfall or irrigation

TILLAGE

Functions

- –Mixing
- –Surface roughness
- –Ridge interval and height
- –Conversion from standing to flat residue

PLANT GROWTH

- Simulates about 100 crops
- Potential daily growth
  - based on radiation and leaf-area-index
- Actual daily growth constrained by stresses:
  - Water
  - Temperature
  - Nutrients
  - Aeration
- CO2 affects
  - growth and water use

PLANT COMPETITION

- Developed in ALMANAC model (Kiniry, et al.)
- Up to 10 crops growing in the same space
- Competing for
  - Light-function of LAI and height
  - Water
  - Nutrients
- Any combination of plants, trees, brush, weeds, grasses, or field crops

APEX

- Management capabilities
  - Irrigation
  - Drainage
  - Furrow diking
  - Buffer strips
  - Terracing
  - Waterways
  - Fertilization
  - Manure management
  - Lagoons
  - Reservoirs
  - Crop rotation and selection
  - Pesticide application
  - Grazing
  - Tillage

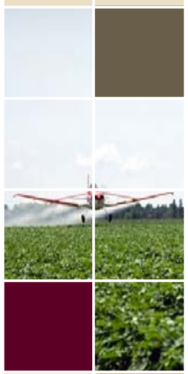
ECONOMICS

Cost and income accounting

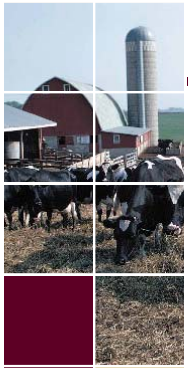
ROUTING COMPONENT

- Water
  - –Overland flow
  - –Channel
  - –Floodplain
  - –Sub-surface
- Sediment
  - –Modified Bagnolds stream power
  - –Deposition – degradation
    - ▪Overland flow
    - ▪Channel
    - ▪Floodplain

ROUTING COMPONENT



- Nutrients and pesticides
  - Soluble materials considered conservative
  - Adsorbed materials sediment transported
  - Enrichment ratio concept



APEX

- Applications
  - Evaluate effects of global climate/CO_2 changes
  - Design environmentally safe, economic landfill sites
  - Design biomass production systems for energy
  - Livestock farm and nutrient management (manure and fertilizer)
  - Forest management
  - Evaluate effects of buffer strips nationally
  - Simulate runoff, erosion/sediment yield, nutrient and pesticide losses from cropland

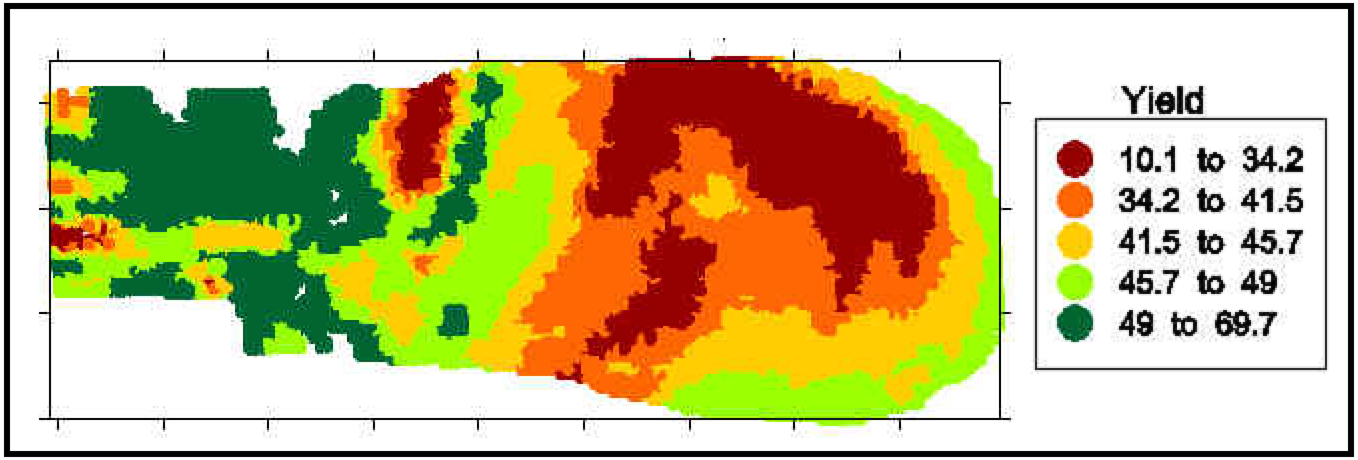
New EPIC/APEX Developments

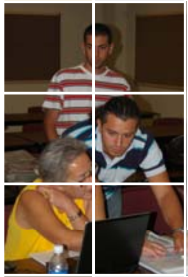
CENTURY CARBON

- Replaced previous mineralization-immobilization component with CENTURY equations.
- Tested with several data sets and reported by Izaurralde.
- Used in National CASMGS runs by Jay Atwood (NRCS).
- Used in National CEAP runs by Jay Atwood.

GEPIC

- GIS EPIC recently developed by Junguo Liu (Switzerland/China).
- Used to simulate and map world wide crop yields.





CroPMan and WinEPIC

- Windows interfaces for EPIC developed at Temple (Gerik and Harman)
- CroPMan is most useful for individual farm crop productivity and was designed for use by crop consultants and extension specialists.
- WinEPIC is more general--useful in solving a range of problems. It was designed for use by researchers and individuals with a greater understanding of crop physiology and related processes.

HAIL OCCURRENCE/DAMAGE COMPONENT

- Developed the hail model as a part of EPIC in cooperation with Drs. Wang and Little of Tarleton State University.
- Model simulates hail occurrence based on daily probabilities.
- Simulates hail damage based on long-term means and standard deviations.
- The model was applied to the state of Kansas and produced realistic results for five major crops in all nine districts of the state.
- Developed for use in crop insurance.

SOUTHERN OSCILLATION INDEX WEATHER SIMULATOR

- EPIC weather simulator has the option to consider the five phases of the SOI in generating rainfall.
- The model generates from one of five monthly weather parameter files depending on the phase of the SOI.
- Particularly useful in drought studies and real time simulation.

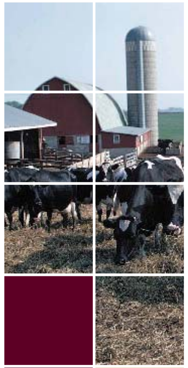
EPIC DYNAMICS--SOIL, ATMOSPHERIC CO_2, TECHNOLOGY

- Rawls equations use to calculate field capacity and bulk density as carbon changes.
- Soil layer thickness changes as bulk density/carbon change.
- Atmospheric CO_2 changes with time--Izaurralde.
- Developed a linear technology change that affects the crop harvest index.
- All of these relationships can be set static or dynamic.

EPIC MANAGEMENT

- Drip irrigation was added as an another irrigation option.
- Water is applied automatically at a specified soil depth.
- Rice paddys--constructed as large furrow dike. Puddling operation added (reduces saturated conductivity of second soil layer).
- Plastic mulch cover added--reduces evaporation; increases runoff.
- Automatic mowing operation added--lawns and golf courses.

THE GRAZING COMPONENT



- Subareas identified by owner.
- Owner may have livestock and poultry (up to ten herds)
- Herd attributes
  - Forage intake rate
  - Grazing efficiency
  - Manure production rate
  - Urine production rate
  - C and soluble and organic N and P fractions in the manure.

CONFINED AREA FEEDING

- Feed area may contain cattle, hogs, poultry, etc.
- Daily manure production is partitioned between liquid and solid.
- Manure applied automatically
  - From lagoons to liquid application fields.
  - From stockpile to solid application fields

MANURE EROSION

- $YMNU=0.25*(Q*q_p)^{0.5}*PE*SL$

  $*RSDM^{0.5}*exp(-.15*AGPM))$

APEX FLOOD ROUTING

- Added hydrograph development and flood routing component.
- Uses a storage depletion method for hydrograph development and the variable storage coefficient flood routing method.
- Hydrographs are routed at any user selected time interval.
- Provides for stream flow simulation not just daily water yield. This feature allows operation on much larger watersheds than previous versions.
- Hydrographs provide potential increased accuracy for routing sediment, nutrients, and pesticides.

APEX SPATIAL RAINFALL SIMULATOR

- Generates storm centroid (draws uniform random number on X and Y axis).
- Generates rainfall amount from parameters of station nearest storm centroid.
- Rainfall amounts of other subareas a function of distance from storm centroid, rainfall duration, and N-S and E-W gradients.
- Final rainfall amounts adjusted with stochastic component.

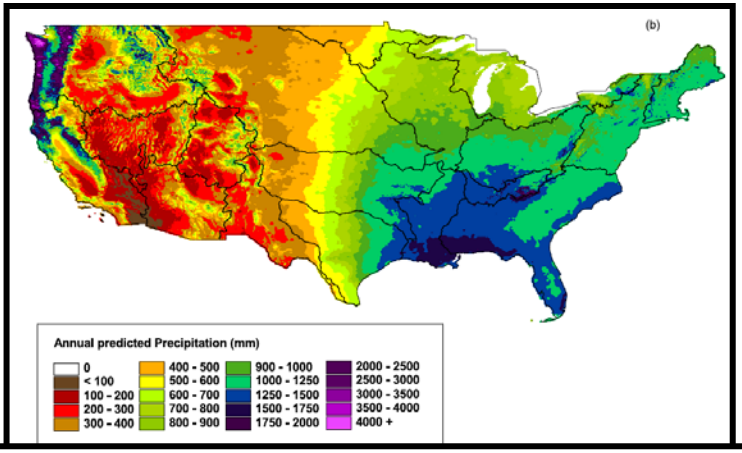
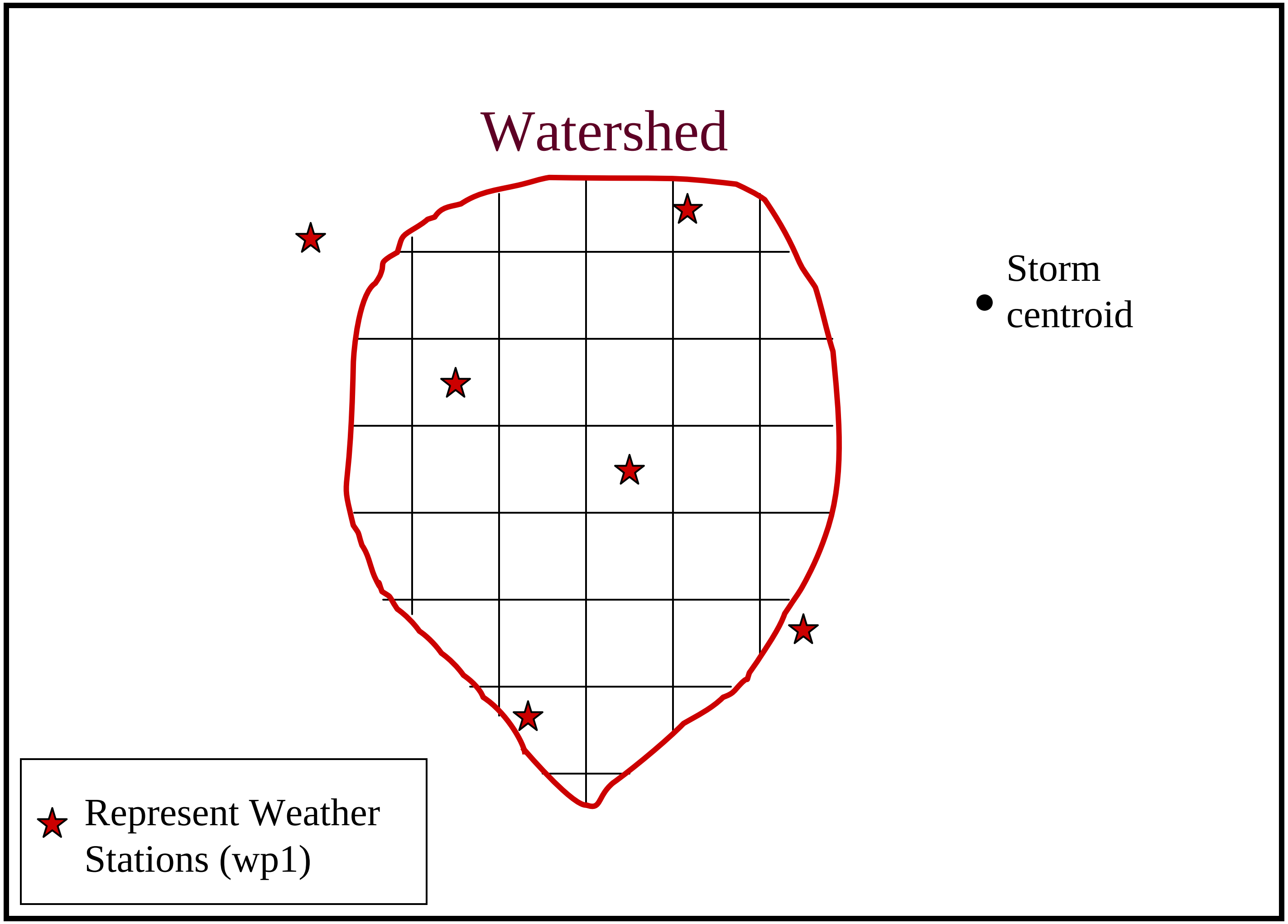


FIG. 7. (b) Annual average predicted precipitation in the period 1960-2001.

SPATIAL RAINFALL GENERATOR



APEX PLAYA RESERVIORS

- Worked with researchers at Texas Tech University in developing APEX reservoir component for application to playas.
- Playas have no spillways--losses are from evaporation and seepage.
- Modified model to reduce storage with deposited sediment.
- Used to determine water availability for ducks and geese.

APEX POINT SOURCES

- A point source can be entered in each subarea.
- Inputs are daily flow and soluble N and P.

RUSLE2

- A modified version of RUSLE2 was added to EPIC and APEX.
- The RUSLE2 slope length equation performed well on steep slopes in China.
- The RUSLE2 C factor equations simulate erosion realistically over a range in tillage (no till/conventional till).

FEEDLOT DUST COMPONENT

- Dust emission
  - Stocking rate
  - Moisture content

- Dust distribution
  - Wind speed
  - Wind direction
  - Distance from feedlot
  - Angle relative to wind direction

DUST DISTRIBUTION