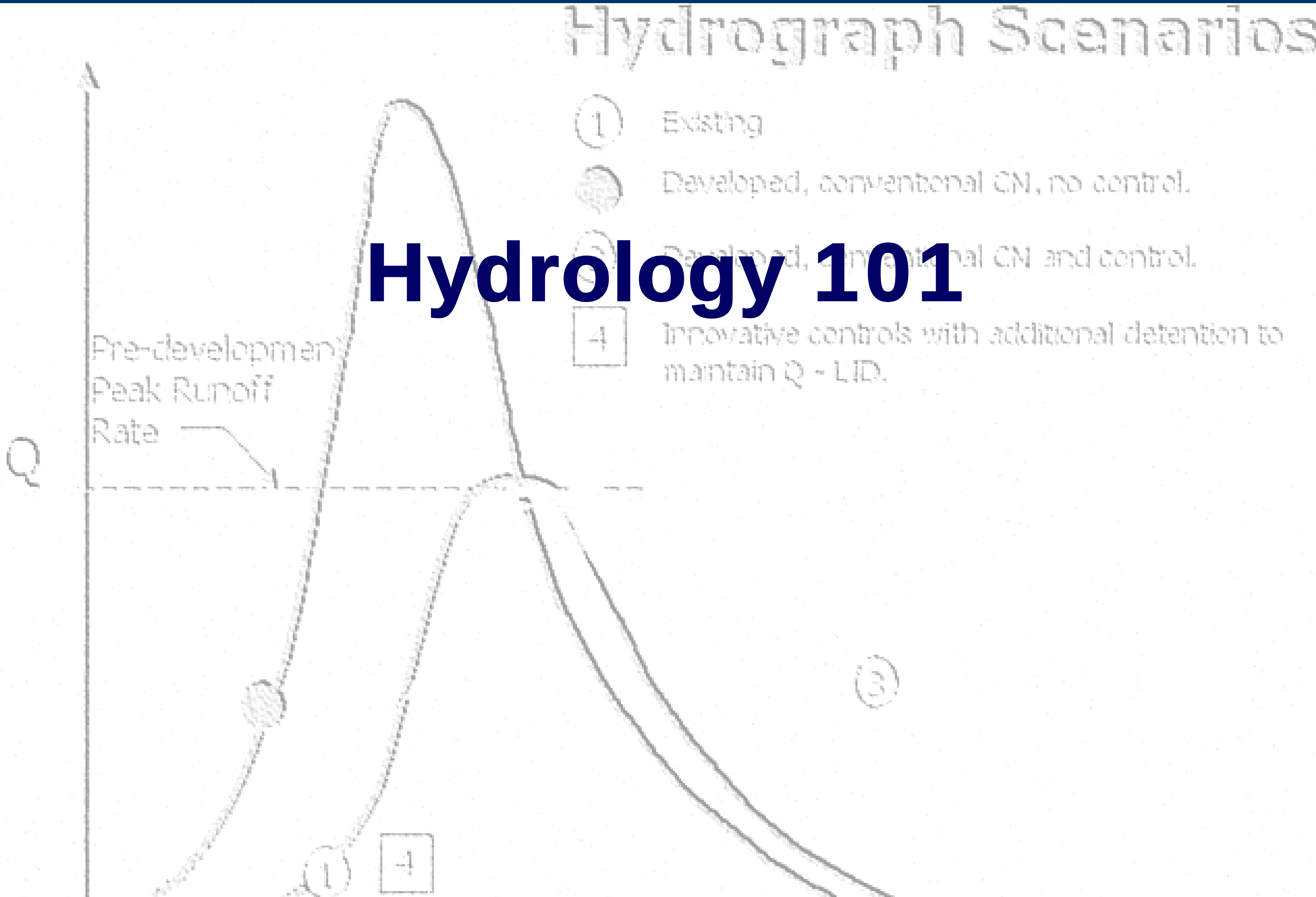
Runoff Hydrology 101

Hydrology 101

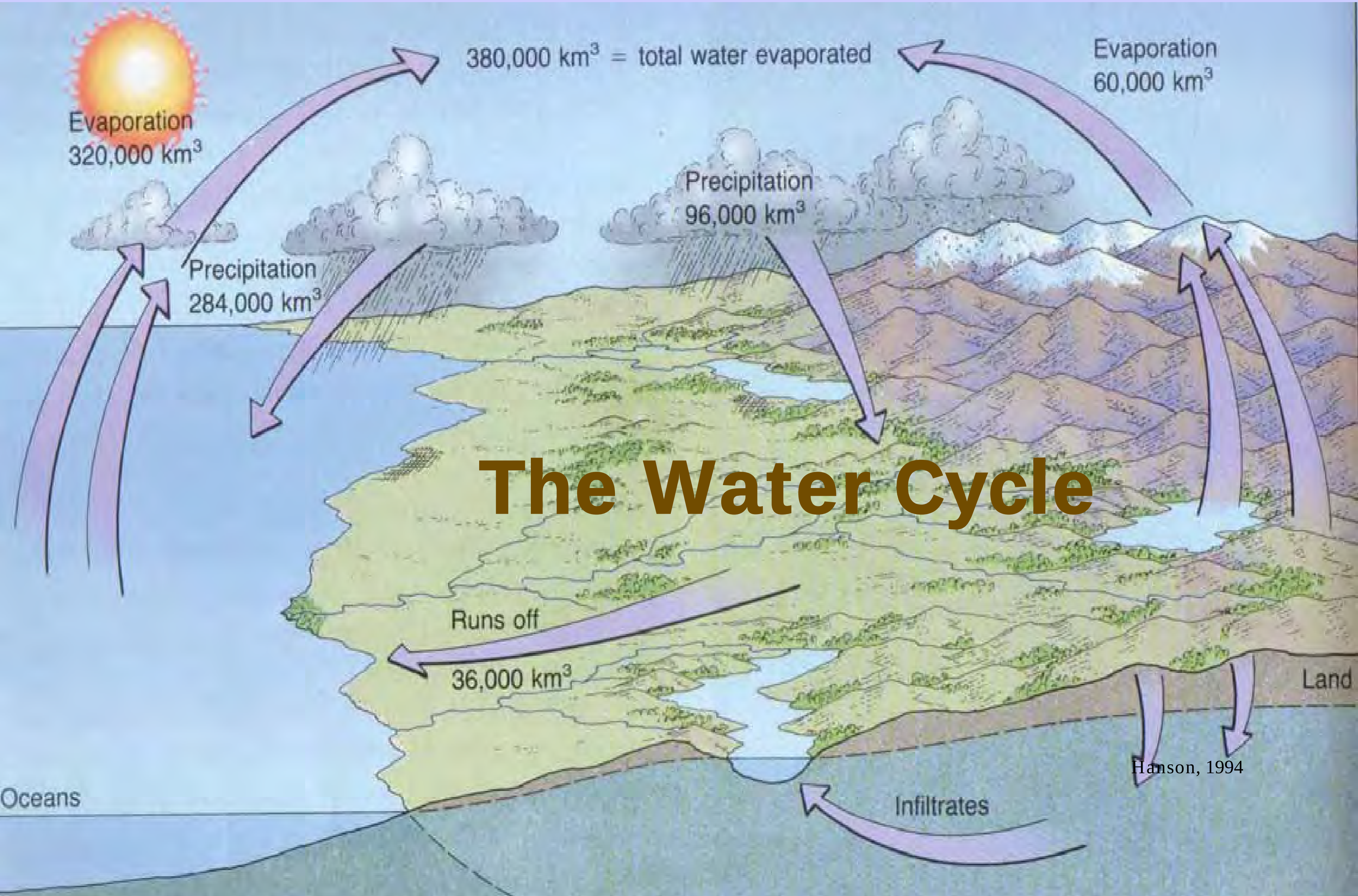


Legislation

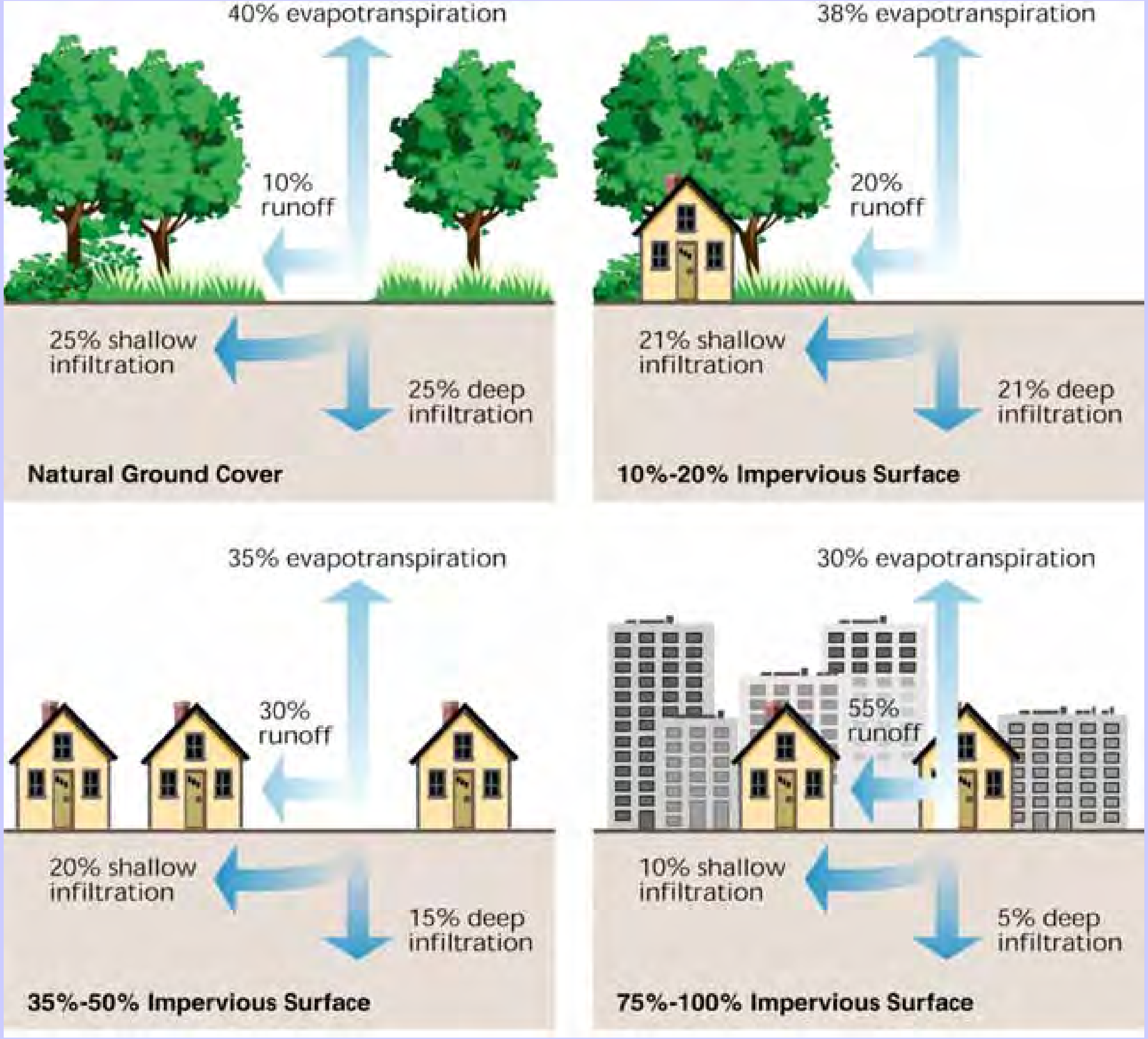
(c) The agency shall develop **performance standards**, design standards, or other tools to enable and promote the implementation of low-impact development and other stormwater management techniques. For the purposes of this section, "low-impact development" means an approach to storm water management that mimics a site's natural hydrology as the landscape is developed. Using the low-impact development approach, storm water is managed on-site and the rate and **volume of predevelopment storm water** reaching receiving waters is unchanged. The calculation of **predevelopment hydrology** is based on native soil and vegetation.

Minnesota Statutes 2009, section 115.03, subdivision 5c

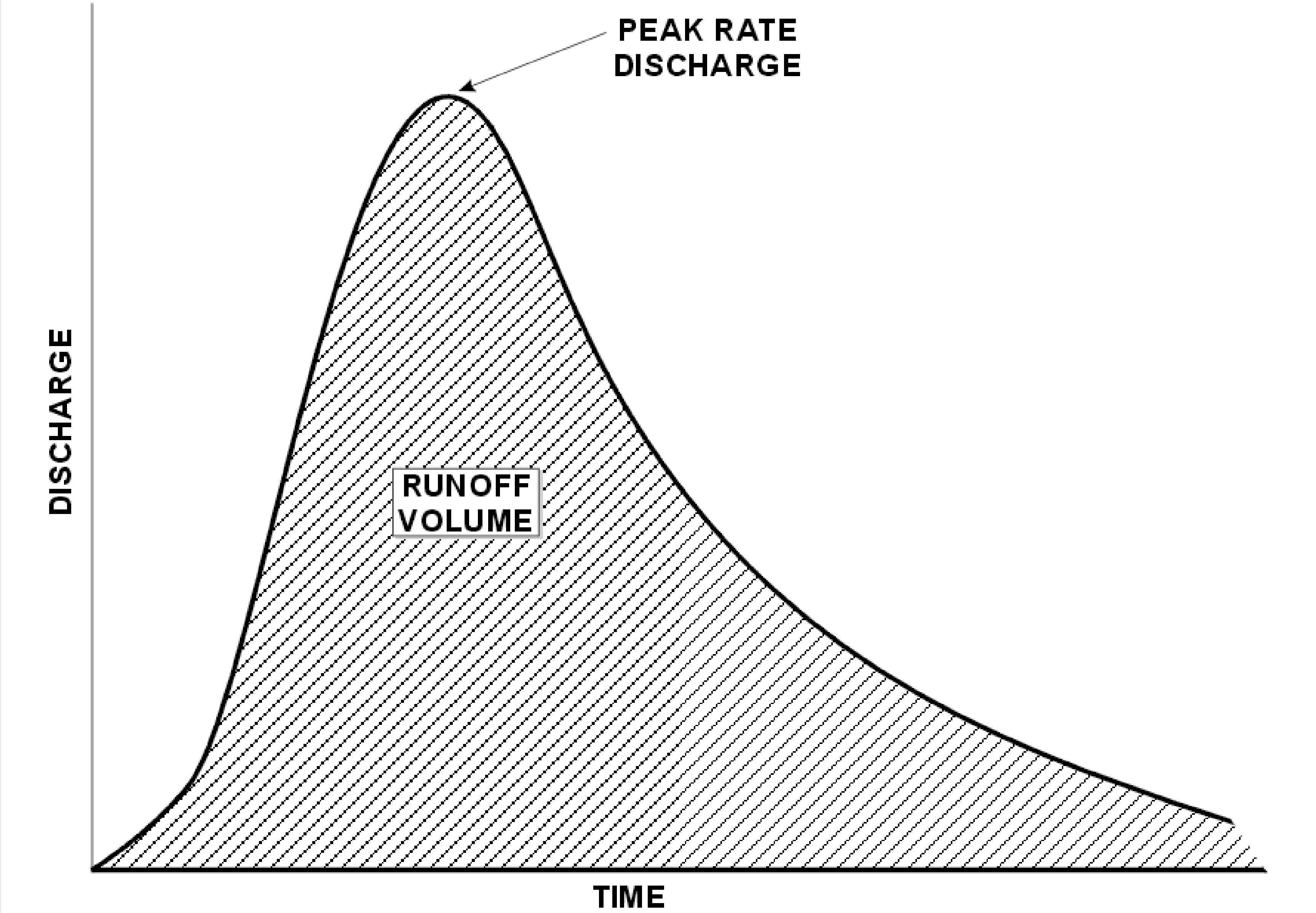
Runoff Hydrology 101



Development Impacts on the Water Cycle



Runoff Hydrology 101

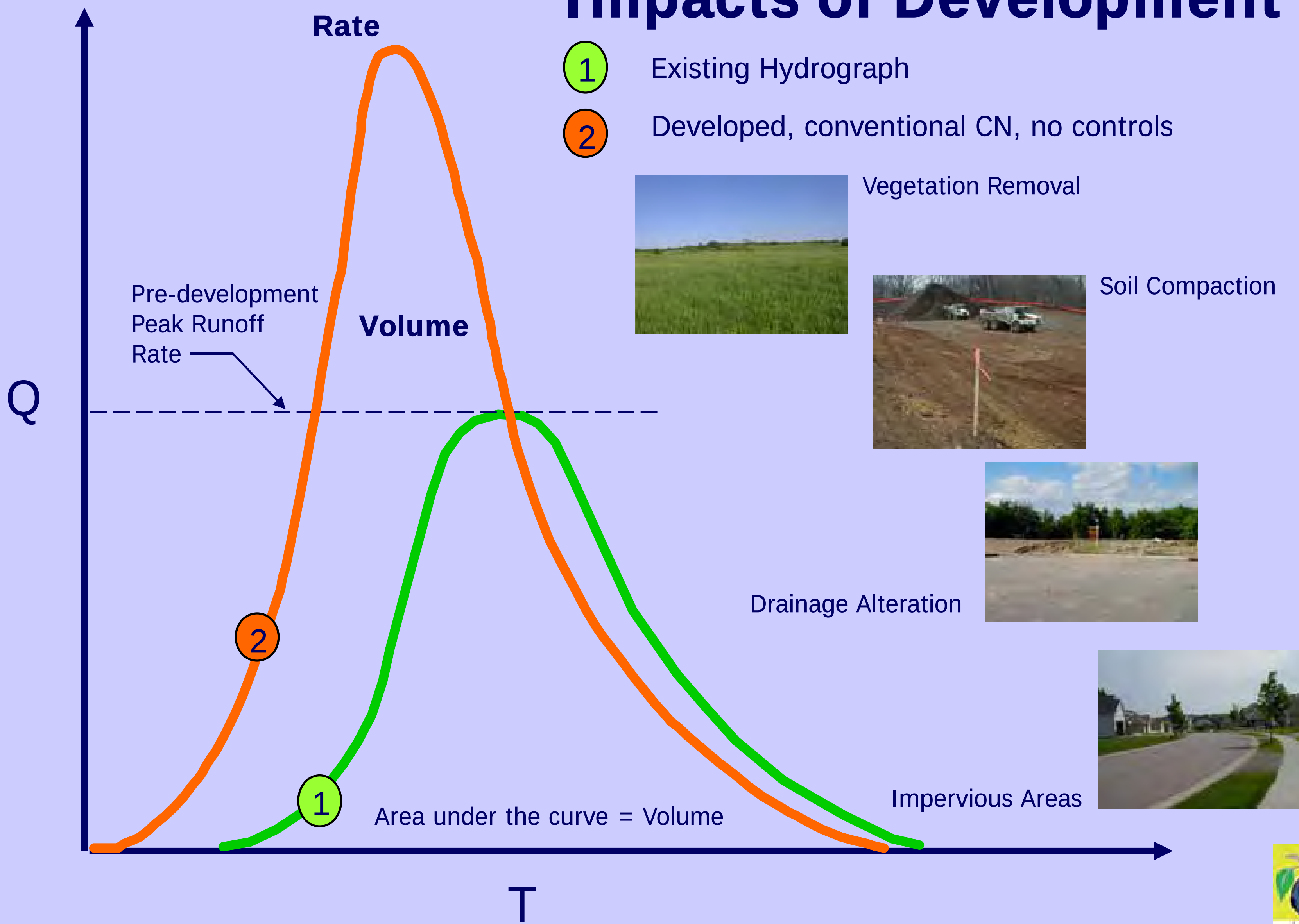


Runoff Hydrology 101

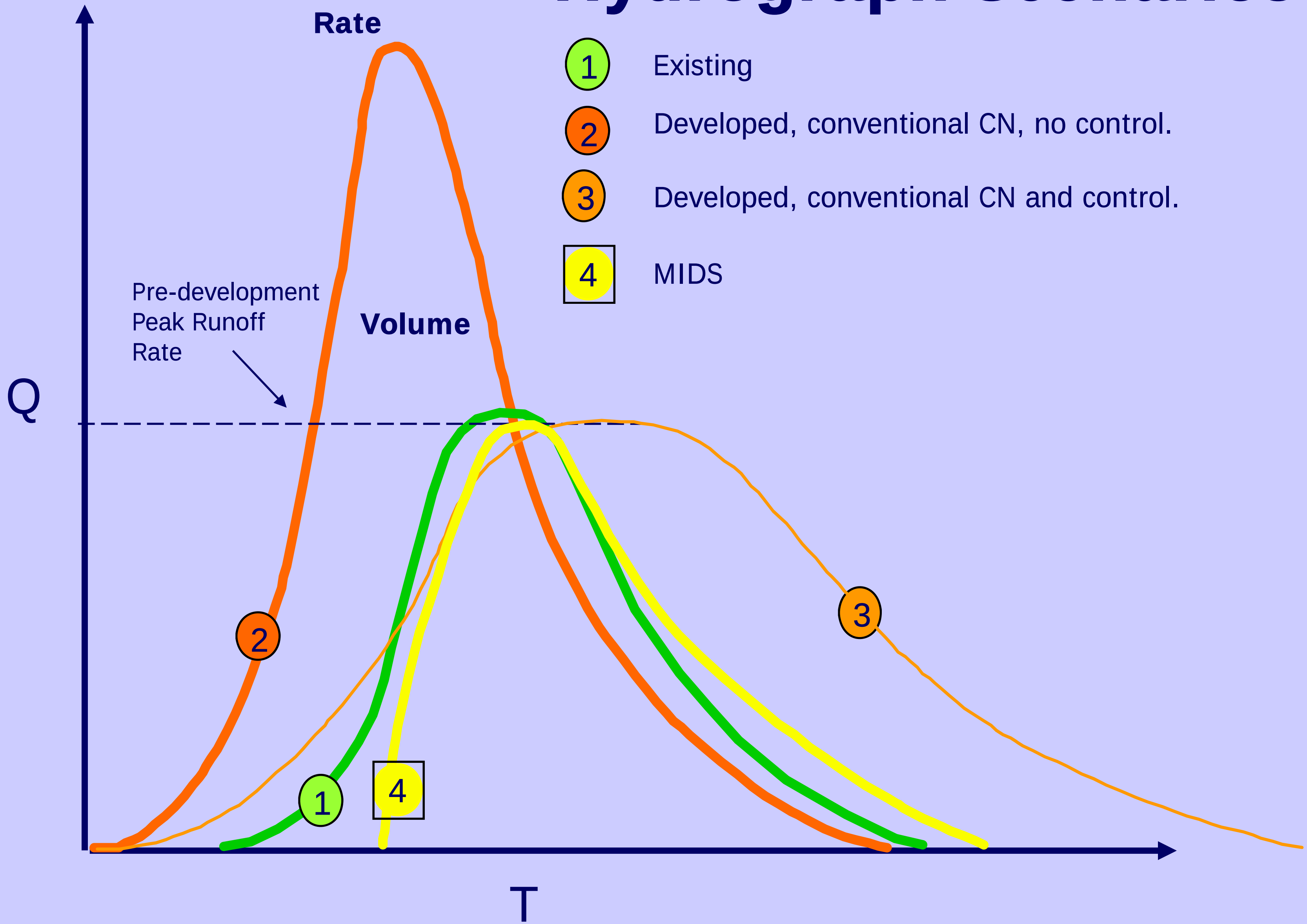
Impacts of Development

1 Existing Hydrograph

2 Developed, conventional CN, no controls



Hydrograph Scenarios



Factors Affecting Q Runoff

- Precipitation
- Antecedent moisture
- Soil permeability
- Watershed area
- Ground cover
- Storage in watershed
- Time parameters

USDA

United States Department of Agriculture

Natural Resources Conservation Service

Conservation Engineering Division

Technical Release 55

June 1986

Urban Hydrology for Small Watersheds

TR-55

Runoff Equations

$$Q = \frac{\left(P - I_a\right)^2}{\left(P - I_a\right) + S} \quad \text{[eq. 2-1]}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

$$I_a = 0.2S \quad \text{[eq. 2-2]}$$

$$Q = \frac{\left(P - 0.2S\right)^2}{\left(P + 0.8S\right)} \quad \text{[eq. 2-3]}$$

$$S = \frac{1000}{CN} - 10 \quad \text{[eq. 2-4]}$$

Runoff Curve Numbers

Commonly used approach to determine runoff

Based on land cover and soils

Simple regression model that is useful for quickly assessing stormwater management practices and assessing impacts of land use changes

Hydrological Soil Group:

Soil groups which are classified according to their drainage potential. Group A soils absorb a lot of water and are deep, well-drained, and composed of sand or gravel. Conversely, Group D soils do not absorb as much water and have a high run-off potential, and have a layer of high clay content near the surface or are shallow soils over bedrock or other material which does not absorb water.

Hydrologic Soil Groups

Table 2-1.—Hydrologic soil groups for U.S. soils (continued)

Soil	Group
BUCHENAU, THICK SOLUM	B
BUCKAROO	C
BUCKBAY	C
BUCKCREEK	C
BUCKEYE	C
BUCKHALL	B
BUCKHOUSE	B
BUCKING	A
BUCKLAKE	C
BUCKLAND	C
BUCKLE	B
BUCKLEBAR	B
[illegible]	D
[illegible]	C
[illegible]	B
[illegible]	
[illegible]	D
[illegible]	D
[illegible]	B
[illegible]	B
[illegible]	B
[illegible]	B
BUCKSKIN	C
BUCKTON	B
BUDE	C
BUDIHOL	D
BUDLEWIS	C
BUELL	B
BUENA VISTA	B
BUFFARAN	D
BUFFCREEK	B
BUFFINGTON	B
BUFFMEYER	B
BUFFORK	C
BUFTON	C
BUHRIG	C
BUICK	C
BUIST	B
BUKO	B
BUKO, WET	C
BUKREEK	B
BULAKE	D
BULKLEY	C
BULL RUN	B
BULL RUN, HARDPAN SUBSTRATUM	C
BULL TRAIL	B
BULLARDS	B
BULLCREEK	D
BULLFLAT	B
BULLFOR	C
BULLION	D
BULLNEL	C
BULLOCK	D
BULLREY	B
BULLUMP	B
BULLYARD	B
BULLWINKLE	D
BULLY	B
BULOW	A
BUNCOMBE	A
BUNDO	B
BUNDORF	D
BUNDY	C
BUNDYMAN	C
BUNEJUG	C
BUNKER	B
BUNKERHILL	D
BUNKWATER	C
BUNKY	C
BUNNELL	B
BUNSELMEIER	B
BUNTINGVILLE	C
BUNYAN	B
BURBANK	A
BURCH	B
BURCHAM	B
BURCHARD	B
BURCHELL	C
BURDETT	C
BUREN	C
BURGESS	C
BURGI	B
BURIBURI	C
BURKE	C
BURKETOWN	C
BURKEVILLE	D
BURKHARDT	B
BURLEIGH	A/D
BURLESON	D
BURLEWASH	D
BURLINGTON	A
BURMAH	D
BURNAC	D
BURNBOROUGH	B
BURNEL	C
BURNETTE	C
BURNHAM	D
BURNSIDE	B
BURNSVILLE	B
BURNSWICK	B
BURNT LAKE	A
BURNTRIVER	B
BURR	D
BURRITA	D
BURROWSVILLE	C
BURSLEY	D
BURSON	C
BURT	D
BURTON	B
BURWELL	C
BUSBY	B
BUSE	B
BUSHER	B
BUSHMAN	B
BUSHNELL	C
BUSHVALLEY	D
BUSKA	B
BUSSY	C
BUSTER	B
BUSTI	C
BUSYWILD	B
BUTANO	C
BUTCHE	D
BUTLER	D
BUTLERTOWN	C
BUTTERFIELD	C
BUTTERMILK	B
BUTTERS	B
BUTTON	D
BUTTONHOOK	B
BUTTONWILLOW	C
BUXIN	D
BUXTON, SOMEWHAT POORLY DRAINED	D
BUXTON, STONY	C
BUXTON, MODERATELY WELL DRAINED	C
BUZZN	A
BYARS	D
BYBEE	D
BYINGTON	C
BYLER	C
BYLO	B
BYNUM	C
BYRAM	C
BYRNIE	D
CABALLO	B
CABARTON	C
CABBA	D
CABBART	C
CABBART, STONY	D
CABBART, WARM	D
CABEZON	D
CABIN	B
CABINET	C
CABLE	B/D
CABO POJO	C
CABOOSE	B
CABOT	D
CABRILLO	C
CABSTON	B
CACHE	D
CACIQUE	C
CACTUSFLAT	C
CADDO	D
CADEVILLE	D
CADILLAC	A
CADIZ	B
CADMUS	B
CADOMA	D
CAESAR	A
CAGEY	C
CAGLE	C
CAGUABO	D
CAGWIN	B
CAHABA	B
CAHONA	B
CAID	B
CAINHOY	A
CAIRO	D
CAJALCO	C
CAJETE	B
CAJON, OVERWASH	A
CAJON, LOAMY SUBSTRATUM	A
CAJON, SILTY SUBSTRATUM	A
CAJON, ALKALI, OVERWASH	A
CAJON, SALINE-ALKALI	B
CAJON, COOL, OVERWASH	A
CAJON, GRAVELLY	A
CAJON, COOL	A
CAJON, WARM	A
CALABAR	D
CALABASAS	B
CALAMINE	D
CALAMITY	D
CALAMUS	A
CALAVERAS	B
CALAWAH	B
CALCO	B/D
CALCOUSTA	B/D
CALCROSS	B
CALD	C
CALDER	D
CALDERWOOD	D
CALDWELL	C
CALDWELL, DRAINED	B
CALE	B
CALEAST	C
CALEB	B
CALEDONIA	B
CALENDAR	C
CALERA	C
CALHI	A
CALHOUN	D
CALICO	C
CALICOTT	A
CALIFON	C
CALIMUS	B
CALITA	B
CALIZA	B
CALKINS	C
CALLABO	C
CALLAHAN	D
CALLAN	C
CALLEGUAS	D
CALLINGS	C
CALLISBURG	C
CALLOWAY	C
CALMAR	B
CALNEVA	C
CALODO	C
CALOOSA	C
CALOUSE	B
CALPAC	B
CALPEAK	D
CALPINE	B
CALROY	B
CALUME	B
CALVERTON	C
CALVIN	C
CALVISTA	D
CALWOODS	D
CALZACORTA	D
CAMAGUEY	D
CAMARGO	B
CAMARILLO	C
CAMARILLO, DRAINED	B
CAMAS	A
CAMAS, STONY	B
CAMATTA	D
CAMBARGE	B
CAMBERN	C
CAMBERT	C
CAMBETH	C
CAMBRIA	B
CAMBRIDGE	C
CAMDEN	B
CAMEEK	D
CAMELBACK	B
CAMEO	B
CAMERON	D
CAMILLUS	B
CAMINO	C
CAMPANA	B
CAMPBELL, MUCK SUBSTRATUM	C
CAMPBELL, DRAINED	B
CAMPBELLTON	C
CAMPCREEK	C
CAMPIA	B
CAMPO	C
CAMPONE	C
CAMPSPASS	B
CAMPUS	B
CAMRODEN	C
CANA	C
CANAAN	C
CANADIAN	B
CANADICE	D
CANALOU	B
CANANDAIGUA	D
CANASERAGA	C
CANAVERAL	C
CANBURN	D
CANDELARIA	B
CANDELERO	C
CANDERLY	B
CANDLER	A
CANDLESTICK	C
CANDOR	A
CANE	C
CANEADEA	D
CANEEK	B
CANELO	D
CANEST	D
CANEYVILLE	C
CANEZ	B
CANFIELD	C
CANISTEO	B/D
CANISTEO, STONY	D
CANINE	B
CANLON	D
CANNELL	B
CANNING	B
CANNON	B
CANNONVILLE	D
CANOE	B
CANOVA	B/D
CANTALA	B
CANTEEN	B
CANTEY	D
CANTINA	C
CANTON	B
CANTON BEND	C
CANTRIL	B
CANTUA	B
CANTUCHE	D
CANUTIO	B
CANWALL	C
CANYON	D
CAPAC	C
CAPAY	D
CAPE	D
CAPE FEAR	D
CAPEHORN	D
CAPERS	D
CAPERTON	D
CAPHOR	B
CAPILLO	C
CAPISTRANO	B
CAPITAN	D
CAPJAC	C
CAPLEN	D
CAPLES	D
CAPLES, DRAINED	C
CAPONA	C
CAPOOSE	C
CAPPS	B
CAPSHAW	C
CAPTINA	C
CAPTIVA	B/D
CAPULIN	B
CARACOLES	D
CARADAN	D
CARALAMPI	B
CARBENGLE	B
CARBO	C
CARBOL	D
CARBONA	D
CARBONDALE	A/D
CARCITY	D
CARDENAS	D
CARDIFF	B
CARDIGAN	B
CARDINGTON	C
CARDON	D
CAREFREE	D
CAREY	B
CAREY LAKE	B
CARGENT	B
CARGILL	C
CARIBEL	B
CARIBOU	B
CARIOCA	B
CARIS	C
CARJO	C
CARLIN	D
CARLINTON	C
CARLISLE	A/D
CARLITO	D
CARLOS	A/D
CARLOTTA	B
CARLOW	D
CARLSBAD	C
CARLSBORG	A
CARLSON	B
CARLSTROM	C
CARLTON	C
CARMACK	B
CARMEL	C
CARMI	B
CARMICHAEL	C
CARMODY	C
CARNASAW	C
CARNEGIE	C
CARNERO	C
CARNEY	D
CAROLINE	C

NOTES: TWO HYDROLOGIC SOIL GROUPS SUCH AS B/C INDICATE THE DRAINED/UNDRAINED SITUATION. MODIFIERS SHOWN, E.G., BEDROCK SUBSTRATUM, REFER TO A SPECIFIC SOIL SERIES PHASE FOUND IN SOIL MAP LEGEND.

Hydrologic Condition:

A rating (good, fair, poor) that is based on a combination of factors that affect infiltration and runoff, including:

- density and canopy of vegetative areas
- amount of year-round ground cover
- amount of grass or close-seeded legumes in rotations
- percent of residue cover on the land surface (good is more than 20%)
- degree of surface roughness

Urban Hydrology for Small Watersheds

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Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

and $I_a = 0.2S$.
ervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas
he drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open
ondition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
nt to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
ral desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN
ea CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
r the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4.
velopment (impervious area percentage) and the CN's for the newly graded pervious areas.

Runoff Curve Numbers for urban areas

Initial Abstraction

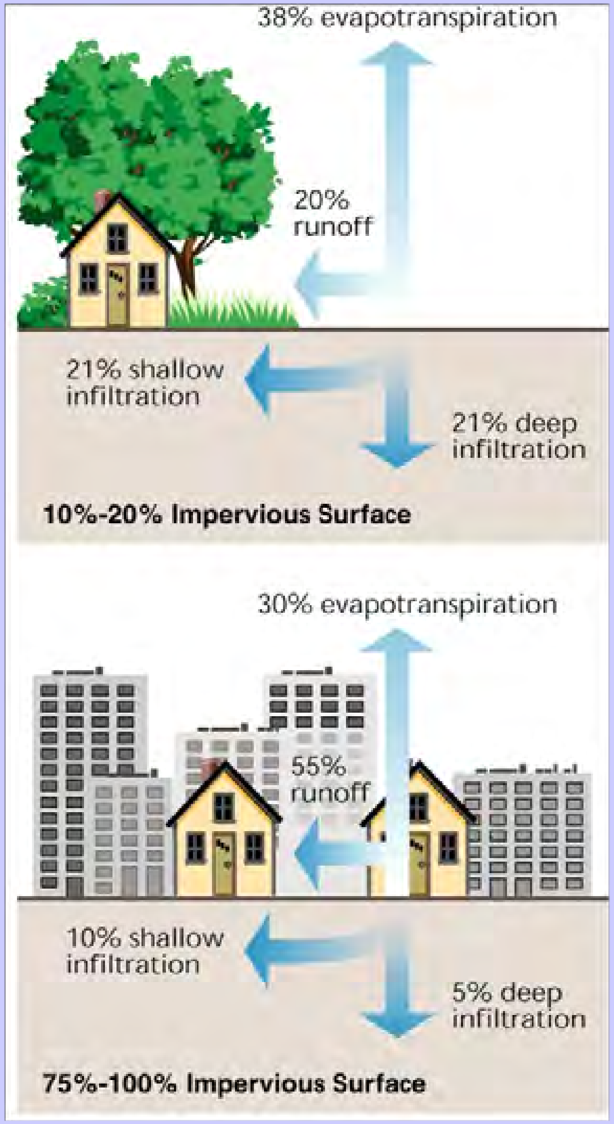
all of the losses that occur before runoff begins, including interception, evaporation, and infiltration.

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

S is the potential maximum retention after runoff begins

Development Impacts on the Water Cycle



I_a represents all of the water that hits the ground that is **unavailable** for runoff.

Some of the water from rainfall is absorbed by plants, some of it sits in puddles or lands right in a lake or pond, some of it evaporates back into the atmosphere, and some of it soaks into the ground.

Runoff Hydrology 101

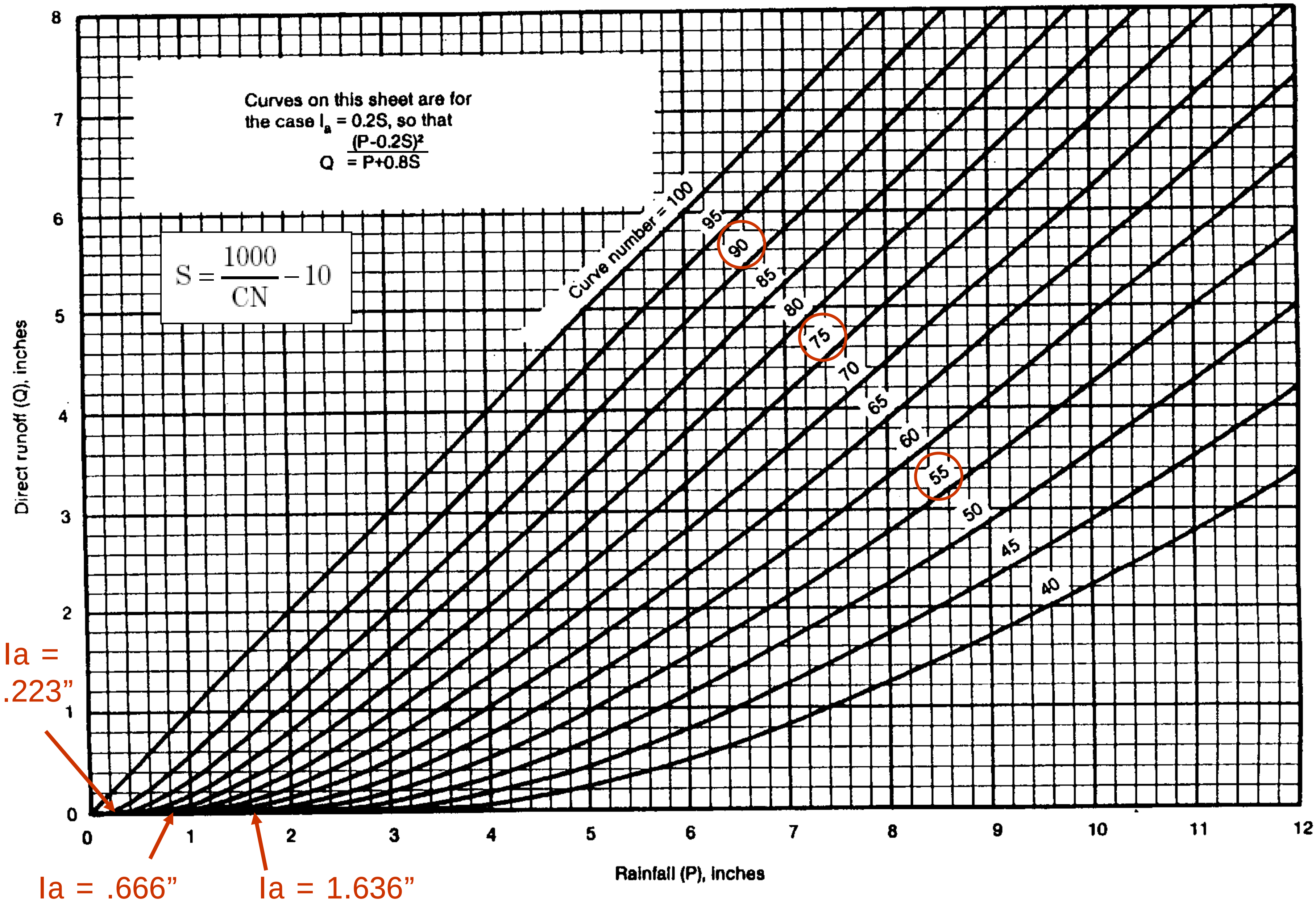
Table 2-2a.—Runoff curve number

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77

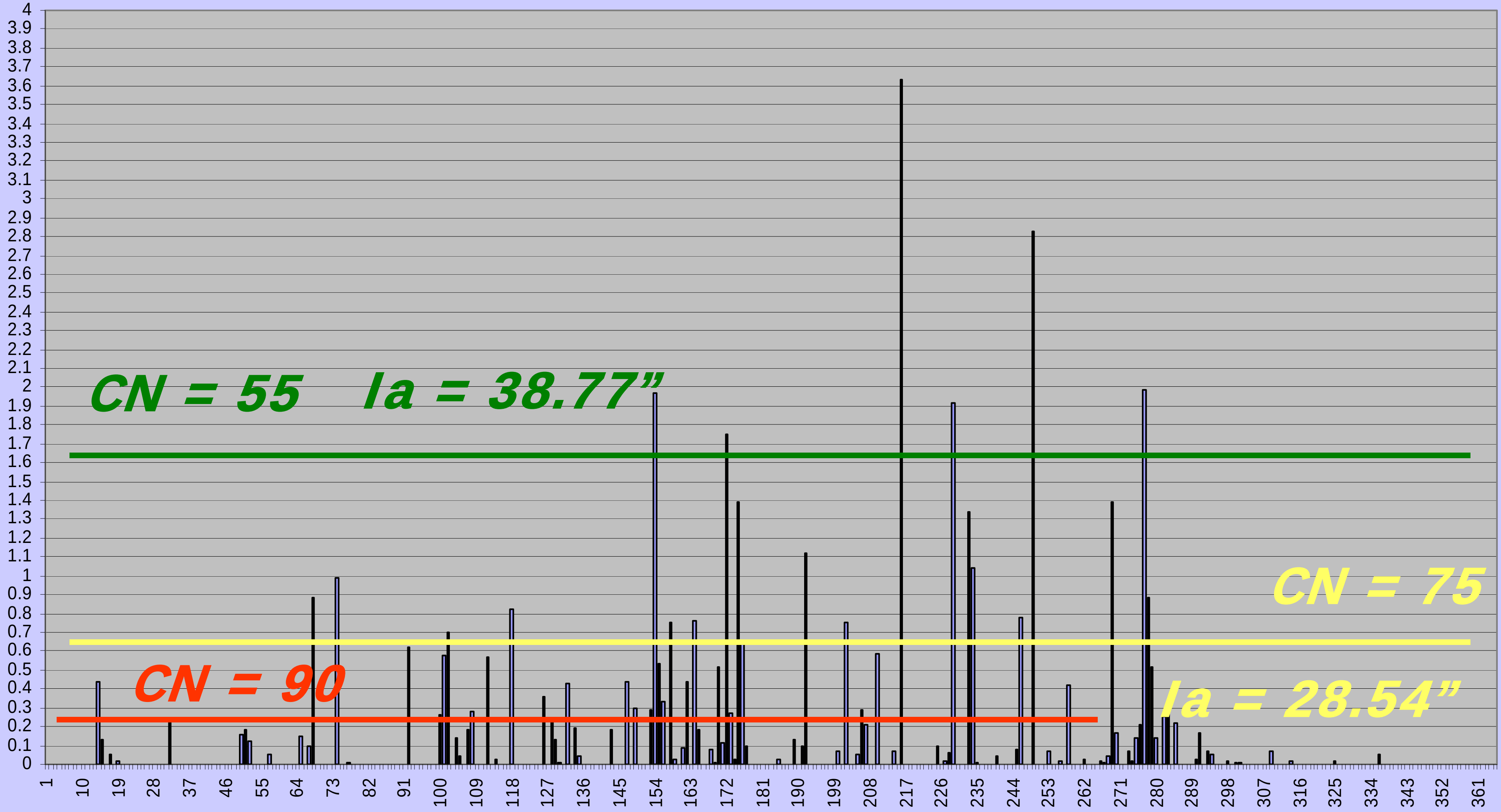
$$I_a = 0.2S \quad \text{[eq. 2-2]}$$

$$S = \frac{1000}{CN} - 10 \quad \text{[eq. 2-4]}$$

Runoff Hydrology 101



Rainfall Distribution



Rosemount, MN 2002 – 43” Average – 34.6”