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Narrator: 97% OF THE EARTH'S WATER
IS CONTAINED IN THE OCEANS.
SOME FORMS OF LIFE FLOURISH
IN THIS SALTY ENVIRONMENT.
BUT HUMANS REQUIRE AN
ABUNDANT SUPPLY OF
FRESHWATER.
LESS THAN 1% OF ALL THE
EARTH'S WATER
IS READILY AVAILABLE FOR
HUMAN CONSUMPTION.
IN THE SEMI-ARID DESERT PLAINS
OF THE SOUTHWEST UNITED
STATES
WHERE RAINFALL AVERAGES
JUST 2 1/2 CENTIMETERS
PER MONTH
TOM MADDOCK STUDIES THIS
SCARCE RESOURCE.
Dr. Maddock: THE REAL PROBLEM
THAT WE HAVE
IS THAT WITH INCREASING
POPULATIONS
AND SHORTAGES OF WATER
WE ARE BECOMING VERY
VULNERABLE.
IN THE SOUTHWEST, THERE'S A

VERY UNIQUE VULNERABILITY HERE
SIMPLY BECAUSE WHERE DO WE GET THE WATER IF THERE IS NO WATER?
Narrator: ACROSS THE COUNTRY IN NORTHERN FLORIDA
THE QUANTITY OF WATER ISN'T AN ISSUE.
RAINFALL AVERAGES AN ABUNDANT 1 1/4 METERS EACH YEAR.

WENDY GRAHAM AND HER COLLEAGUES
EVALUATE AND MODEL THE IMPACTS
OF INDUSTRIAL AND AGRICULTURAL LAND USE
THREATENING THE WORLD'S LARGEST COLLECTION
OF FRESHWATER SPRINGS.
Dr. Graham: RIGHT NOW, THE BIGGEST QUESTION
IS HOW FAR WE CAN STRESS THE SYSTEM
AND NOT PUSH IT PAST THE POINT OF NO RETURN.
Narrator: BOTH RESEARCHERS ARE WORKING TOWARDS A SUSTAINABLE FUTURE
TO PROTECT THE WATER NEEDED

BY OUR SPECIES AND OUR PLANET.

ARIZONA IS ONE OF THE FASTEST-GROWING STATES
IN THE U.S.
THE CONSEQUENT DEMAND ON FRESHWATER
FOR PERSONAL, INDUSTRIAL, AND AGRICULTURAL USE
IS DEPLETING THE NATURAL RESOURCE
AND DESTROYING THE ENVIRONMENT.
I'M TOM MADDOCK.
I'M AT THE UNIVERSITY OF ARIZONA
AND I STUDY HYDROLOGY.
I WORK IN THE AREA
OF
GROUND-WATER/SURFACE-WATER INTERACTIONS.
BASICALLY, THE DIFFERENCE
BETWEEN GROUND WATER AND SURFACE WATER
IS YOU CAN FLOAT A STICK IN SURFACE WATER.
IN GROUND WATER, YOU REALLY CAN'T DO THAT
EXCEPT MAYBE LOOKING DOWN A WELL
AND DROPPING THE STICK DOWN

THE WELL.
Narrator: SURFACE WATER IS TYPICALLY FOUND
IN LAKES, RIVERS, AND STREAMS.
GROUND WATER IS FOUND
BENEATH THE EARTH'S SURFACE
IN SMALL PORES AND FRACTURES
FOUND WITHIN LARGE ROCK FORMATIONS.
WHEN THIS WATER IS READILY AVAILABLE FOR HUMAN USE
THESE FORMATIONS ARE CALLED AQUIFERS.
ALMOST ALL OF THE NATURAL SURFACE WATER IN ARIZONA
HAS BEEN DEVELOPED
LEAVING ONLY GROUND WATER AVAILABLE FOR HUMAN CONSUMPTION.
Dr. Maddock: THE PROBLEM IN THE SOUTHWEST
IS THAT WE BASICALLY ARE
HAVING CONTINUED GROWTH
AND, IN MANY PLACES, THE ONLY PLACE
THAT YOU CAN GET WATER TO SUSTAIN THAT GROWTH
IS FROM GROUND-WATER DEVELOPMENT.
UNFORTUNATELY, GROUND WATER IS MORE AVAILABLE NEAR THE STREAMS

THAN IT IS OTHER PLACES.
IT'S WHAT WE CALL THE WILLIE SUTTON PRINCIPLE.
WILLIE SUTTON WAS A BANK ROBBER
AND WAS ONCE ASKED WHY HE ROBBED BANKS, AND HE SAYS "WELL, THAT'S BECAUSE THAT'S WHERE THE MONEY IS."
IN THE SAME INSTANCE, THE WELLS GO IN NEAR THE RIVER BECAUSE THAT'S WHERE THE WATER IS.
BUT, OF COURSE, THE GROUND-WATER PUMPING INTERFERES WITH THE SURFACE-WATER SYSTEMS.
IT ESSENTIALLY DEPLETES SURFACE WATER
AND YOU END UP WITH A CONFLICT.
THIS IS A VERY, VERY LIMITED QUANTITY OF WATER
THAT YOU ARE ESSENTIALLY ADDING A LOT MORE STRAWS INTO.
AND ULTIMATELY WHAT HAPPENS IS YOU RUN OUT OF WATER.
Narrator: PUMPING A WELL THAT'S NEAR A STREAM
CREATES A CONE OF DEPRESSION

THAT DRAWS IN WATER FROM THE STREAM
OR INTERCEPTS WATER THAT WOULD HAVE ARRIVED
AT THE STREAM.
AS THE DEMAND ON GROUND WATER INCREASES
THE LEVEL OF SURFACE WATER IN STREAMS AND RIVERS
DECREASES.
A STREAM THAT WAS ONCE GAINING WATER FROM AQUIFERS
BECOMES A LOSING STREAM UNTIL IT LOSES ALL OF ITS WATER.

Dr. Maddock: IT'S A PHYSICAL PROBLEM
IN TERMS OF THE FACT THAT YOU'RE TAKING WATER OUT OF THE STREAM.
IT'S AN ECOLOGICAL PROBLEM
IN THE FACT THAT YOU'RE REDUCING HABITAT FOR NOT ONLY PLANTS
BUT ALSO FOR BIRDS AND ANIMALS THAT MAY LIVE IN THAT.
AND THEN IT'S AN INTERNATIONAL PROBLEM.
ALMOST EVERY COUNTRY IN THE WORLD
THAT USES GROUND WATER AS A

RESOURCE
IS HAVING TROUBLES WITH IT
AFFECTING SURFACE-WATER
SYSTEMS.
AND IT'S AN AREA WHICH
GENERALLY IN THE PAST
HASN'T BEEN STUDIED.
Narrator: TO FURTHER
UNDERSTAND THE EFFECTS OF
WATER LEVELS
ON THE ENVIRONMENT
MADDOCK AND HIS TEAM
ANALYZE DATA
GATHERED FROM THE LUSH
AREAS SURROUNDING RIVERS
AND STREAMS
CALLED RIPARIAN SYSTEMS.
Dr. Maddock: BASICALLY, VERY
CLOSE TO THE STREAM
YOU'RE GONNA FIND AN
ABUNDANCE OF TREES
LIKE COTTONWOODS AND
WILLOWS, BUSHES, GRASSES
THAT EVENTUALLY JUST
DISAPPEAR AS YOU MOVE
FURTHER AWAY.
AND THIS IS CALLED A RIPARIAN
SYSTEM.
BECAUSE ALL THE PLANTS ARE
THERE
THE ANIMALS AND BIRDS HABITAT
THAT AREA, TOO.

SO, IF YOU REDUCE THAT HABITAT
EITHER BY DROPPING A WATER
TABLE
OR REDUCING A SURFACE-WATER
SUPPLY
ESSENTIALLY WHAT YOU'RE
DOING IS DESTROYING NOT ONLY
PLANT LIFE
BUT PROBABLY ANIMAL LIFE, TOO.
AND THAT IS THE AREA THAT I'M
TRYING TO UNDERSTAND --
HOW LITTLE WATER CAN THESE
SYSTEMS SURVIVE WITH
AND HOW THEY WORK.
Narrator: TO ANSWER THIS
QUESTION
MADDOCK CREATES
MATHEMATICAL MODELS.
Dr. Maddock: THERE ARE CERTAIN
PROCESSES
THAT CAN ONLY BE DESCRIBED
MATHEMATICALLY.
WHAT WE'VE BEEN ABLE TO DO IS
TO INTRODUCE
INTO GROUND-WATER-FLOW
MODELS TRANSPIRATION
PROCESSES
WHICH REFLECT THE BEHAVIOR
OF THE PLANTS
IF YOU RAISE AND LOWER THE
WATER TABLE.
IN THE PAST, THAT HADN'T BEEN

ABLE TO BE DONE.
Narrator: TRANSPIRATION IS THE PROCESS
IN WHICH WATER VAPOR IS LOST FROM LAND PLANTS
TO THE ATMOSPHERE.
THIS PROCESS CAUSES MOVEMENT OF WATER THROUGH THE PLANT
FROM SOIL TO AIR.
WATER ENTERS A TREE THROUGH ITS ROOT SYSTEM
MOVES THROUGH XYLEM TISSUE --
THE VERY THIN STRAWS LINING THE INSIDE OF THE TREE --
BEFORE EVAPORATING INTO THE ATMOSPHERE THROUGH ITS LEAVES.
Dr. Maddock: SOME OF THE TREES IN THE RIPARIAN SYSTEM
CAN USE QUITE AN ASTOUNDING AMOUNT OF WATER.
IT'S BEEN ESTIMATED THAT UNDER, SAY, PERFECT CONDITIONS
A HEALTHY COTTONWOOD
CAN TAKE UP AS MUCH AS 90 GALLONS PER DAY OF WATER
WHICH IS ABOUT THE SAME AS HALF OF A NORMAL HOUSEHOLD
HERE IN THE SOUTHWEST.

BUT WE'RE TALKING ABOUT A FAIRLY SUBSTANTIAL AMOUNT OF WATER
THAT'S BEING TRANSPIRED BY THE TREES.
ONE OF THE THINGS THAT HAD BEEN SUGGESTED AT ONE TIME WAS PERHAPS ONE WAY TO SAVE WATER IN THE RIVER
IS TO CUT DOWN ALL THE TREES ALONG IT.
THE PROBLEM IS, IS WHEN YOU DO THAT
REGULAR EVAPORATION TAKES OVER
AND YOU CAN END UP ACTUALLY LOSING MORE WATER
WITH REGULAR EVAPORATION THAN YOU WOULD FROM TRANSPIRATION FROM THE TREES.
THERE WERE SEVERAL STUDIES DONE BY THE BUREAU OF RECLAMATION
AND ONE BY THE U.S. GEOLOGICAL SURVEY
THAT ESTABLISHED THIS.
Narrator: TO BETTER UNDERSTAND THE EFFECTS OF WATER DEPLETION
IN RIPARIAN ZONES
MADDOCK'S COLLEAGUE, DR.

KATE BAIRD
IS MEASURING THE AMOUNT OF
WATER USED BY VEGETATION
NEAR THE SAN PEDRO RIVER
A RIVER THAT HAS BEEN IN
DECLINE OVER THE PAST
DECADE.
FOR EACH TREE, BAIRD
DETERMINES THE VOLUME OF
WATER
TRAVELING THROUGH THAT TREE.
TO DO THIS, SHE MEASURES BOTH
THE VELOCITY
OF THE WATER MOVING UP THE
TREE
AND THE AREA OF ITS XYLEM
TISSUE.
Dr. Baird: SO, IF I WANTED TO
UNDERSTAND
HOW MUCH WATER IS FLOWING
THROUGH THE TREE
OR HOW MUCH WATER THIS TREE
REALLY NEEDED IN ANY DAY
WE WOULD SIMPLY PEEL OFF A
SMALL PART OF THIS BARK
DRILL TWO VERY SMALL HOLES
INTO THE TREE
AND INSERT THIS HEAT PROBE.
Narrator: A DOUBLE PROBE IS
USED TO MEASURE THE VELOCITY
OF WATER
MOVING THROUGH THE TREE.

THE LOWER PROBE IS HEATED TO A KNOWN TEMPERATURE.
THE OTHER MEASURES THE TEMPERATURE
OF BOTH THE TREE AND WATER IN THE TREE.
IF WATER IS NOT FLOWING, THE UPPER PROBE
RECORDS THE MAXIMUM TEMPERATURE DIFFERENCE POSSIBLE.
THE FASTER THE FLOW OF WATER
THE MORE HEAT IS DISSIPATED
AND THE MORE THE TEMPERATURE IS SIMILAR.
IN THIS WAY, RESEARCHERS CAN DETERMINE
THE AMOUNT OF WATER USED BY THAT TREE.
BAIRD ALSO TAKES SMALL CORE SAMPLES OF THE TREE
TO MEASURE THE WIDTH OF THE XYLEM
AND THE TOTAL AREA OF XYLEM IN THE TREE.
VARIOUS TREES AND PLANTS IN A RIPARIAN SYSTEM
REQUIRE DIFFERENT AMOUNTS OF WATER.
WITH THESE DATA
THE TEAM CAN DETERMINE THE WATER NEEDS OF THE RIPARIAN

SYSTEM.
WHAT WE DO IS DEVELOP A CURVE
THAT RELATES THE WATER LEVEL TO HOW WELL THE PLANT TRANSPIRES
HOW WELL IT USES THE WATER.
AND WE HAVE THREE CRITICAL POINTS.
THE FIRST POINT IS CALLED THE EXTINCTION DEPTH
AND THAT IS IF THE WATER TABLE DROPS BELOW THAT POINT
THE PLANT WILL EXPIRE.
AND THEN IF THE WATER TABLE RISES, THERE WILL BE A POINT
AT WHERE THE PLANT USES THE MAXIMUM AMOUNT OF WATER.
IN OTHER WORDS, THIS IS ITS MOST EFFICIENT POINT.
AND THEN AS THE WATER TABLE RISES EVEN FURTHER
WHAT HAPPENS IS THAT YOU CAN ACTUALLY END UP TO THE POINT
WHERE YOU DROWN THE PLANT,
WHERE IT HAS TOO MUCH WATER.
AND ONE OF THE THINGS THAT OUR RESEARCHERS DO
IS TO TRYAND DEVELOP THESE CURVES
FOR THESE PLANTS FOR THESE VARIOUS PLANT GROUPS

RATHER THAN SINGLE SPECIES.
SO, WHAT HAPPENS IS, IS THAT
WE MAY HAVE 5,000 SPECIES
BUT THEY MAY BE ABLETO BE
GROUPED
IN AS LITTLE AS FOUR OR FIVE
DIFFERENT TYPES.
Narrator: GROUPING THE TREES BY
SUCH FACTORS AS ROOTING
DEPTH
WATER-LEVEL TOLERANCE, AND
TRANSPIRATION RATE
SCIENTISTS CAN DETERMINE THE
WATER NEEDS OF THIS
ECOSYSTEM
TO ENSURE ITS FUTURE HEALTH.
Dr. Baird: THE SAN PEDRO RIVER
IS ONE OF THE LAST REMAINING
FREE-FLOWING RIVERS
IN THE SEMI-ARID SOUTHWEST.
OUR RESEARCH IS SHOWING
THAT THE RIVER IS ALREADY IN
DECLINE
AND POSSIBLY AT A CRITICAL
TURNING POINT.
Narrator: IF THE PROBLEM OF THE
SAN PEDRO RIVER IS IGNORED
IT MAY SHARE THE FATE OF THE
RILLITO RIVER
JUST 160 KILOMETERS AWAY.
WE'RE STANDING ALONG THE
BANKS OF THE RILLITO RIVER

IN TUCSON, ARIZONA
AND LOOKING AT WHAT HAPPENS
TO A RIVER
ONCE IT BECOMES
DISCONNECTED FROM THE
GROUND WATER.
HISTORICALLY, THIS DRY
RIVERBED HAD WATER FLOWING
THROUGH IT
AND LINING THE BANKS WERE
COTTONWOODS AND WILLOW
AND OTHER NATURAL
VEGETATION.
YEARS OF GROUND-WATER
PUMPING FOR HUMAN USE
HAVE CAUSED THE
GROUND-WATER TABLE TO
DECLINE
AND ONCE THE GROUND-WATER
TABLE DECLINES BELOW THE
RIVERBED
THE RIVER ESSENTIALLY
BECOMES DISCONNECTED
AND YOU LOSE A FUNCTIONING
RIVER.
Dr. Maddock: THE TROUBLE IS
THAT MOST PEOPLE DON'T
UNDERSTAND
WHAT THE SUSTAINABILITY IS IN
THEIR PARTICULAR AREA.
IF YOU'RE LUCKY ENOUGH TO
HAVE A MIXTURE OF

SURFACE-WATER
AND GROUND-WATER SYSTEMS
THAT YOU CAN EXTRACT WATER
FROM TO GET YOUR WATER
SUPPLY
YOU'RE IN BETTER SHAPE THAN IF
YOU HAVE EITHER ONE OF THESE
AND NOT THE OTHER, AND THE
REASON FOR THAT IS
IS THAT IN WET YEARS WHEN YOU
HAVE LOTS OF WATER
YOU CAN MAYBE RECHARGE THE
AQUIFER.
IN DRY YEARS WHEN YOU DON'T
HAVE A LOT OF SURFACE WATER
YOU CAN EXTRACT WATER FROM
THE GROUND-WATER SYSTEM.
SO, THERE'S KIND OFA
SUSTAINABLE QUANTITY.
THE PRIMARY ISSUE THAT CITIES,
PARTICULARLY IN THE
SOUTHWEST
ARE HAVING TO LOOK AT IS THE
IDEA OF SUSTAINABILITY.
IN OTHER WORDS
HOW MUCH WATER DOES IT TAKE
TO SUSTAIN A CERTAIN
LIFESTYLE, A CERTAIN QUALITY
OF LIFE?
Narrator: MADDOCK HOPES TO USE
HIS MODELS TO EDUCATE PEOPLE
ABOUT THE EFFECTS OF FALLING

WATER TABLES
AND TO HELP DETER
OVERPOPULATION OF THESE
AREAS IN THE FUTURE.
Dr. Maddock: THE RESEARCH THAT
WE'RE DOING
ON
SURFACE-WATER/GROUND-WATE
R SYSTEMS
IS TIED IN TO THE MANAGEMENT
OF A REGIONAL WATER SUPPLY
WHICH, IN TURN
IS CONNECTED TO A STATE OR
COUNTRY WATER SUPPLY
WHICH, IN TURN, IS CONNECTED
INTO INTERNATIONAL ISSUES
INVOLVING WATER SUPPLY
SO THAT THE THINGS THAT WE
STUDY IN OUR AREA
ULTIMATELY LEAD TO PRODUCING
WATER-MANAGEMENT
CAPABILITIES
THAT ARE USED IN OTHER PLACES
THROUGHOUT THE WORLD.
Narrator: WHILE MADDOCK'S
RESEARCH
IS BASED IN THE SEMI-ARID
SOUTHWEST
PROFESSOR WENDY GRAHAM'S
RESEARCH LIES ACROSS THE
COUNTRY
IN AN AREA WHERE THE QUANTITY

OF WATER ISN'T AN ISSUE
WITH 50 INCHES, OR 1 1/4 METERS,
FALLING ANNUALLY.
BUT THE QUALITY OF THE
FRESHWATER
IS IN DANGER OF BEING
IRREPARABLY DAMAGED.
NORTHERN FLORIDA IS HOME TO
CATTLE RANCHES
INDUSTRIAL AGRICULTURE
AND A HUMAN POPULATION
GROWING AT AN
UNPRECEDENTED RATE.
ALL OF THESE USERS HAVE THE
POTENTIAL
TO DEGRADE THE ABUNDANT
WATER RESOURCES THAT FLOW
HERE.
Dr. Graham: MY NAME IS WENDY
GRAHAM.
I'M A PROFESSOR AND DIRECTOR
OF THE WATER INSTITUTE
AT UNIVERSITY OF FLORIDA.
A VERY INTERESTING PLACE,
HYDROLOGICALLY.
THERE'S A LOT OF FRESHWATERA
ND A LOT OF PEOPLE
AND A LOT OF LAND-USE
CHANGES GOING ON.
WELL, THE LARGEST USER OF
WATER IN THIS REGION OF
FLORIDA

IS AGRICULTURE.
AND, IN FACT, IN FLORIDA, IN GENERAL
THE LARGEST USER OF FRESHWATER IS AGRICULTURE.
BUT PUBLIC WATER SUPPLY IS A CLOSE SECOND
AND, IN THE NOT TOO DISTANT FUTURE, I'M SURE WILL CATCH UP AND OVERTAKE AGRICULTURE AS THE MAJOR USER.

I GREW UP IN THE BAHAMAS.
WE LIVED ON A LITTLE ISLAND,
AND WE HAD OUR WELL HERE
AND THEN WE HAD OUR SEPTIC TANK HERE.
AND THAT PROXIMITY I ALWAYS FOUND KIND OF FASCINATING.
AND I'D SPENT MOST OF MY TIME OUT OF DOORS.
THERE WEREN'T A LOT OF INDOOR DISTRACTIONS --
VERY FEW MOVIE THEATERS, NO SHOPPING MALLS.
SO WE SPENT OUR FRIDAYS AND SATURDAYS
ON SAILBOATS IN THE OCEAN.
AND THEN WE'D GET HOME TO SHOWER
AND THE WATER WOULD BE OFF
'CAUSE WE ONLY HAD WATER

FROM 6:00 A.M. TO 2:00 IN THE AFTERNOON.
SO, WE HAD VERY LIMITED FRESHWATER
AND VERY ABUNDANT SALT WATER.
AND I JUST GOT INTERESTED IN WATER RESOURCES
THINKING ABOUT THAT DICHOTOMY.
RIGHT NOW, MOST OF THE FIELDWORK I'M INVOLVED IN
IS IN THE SUWANNEE RIVER BASIN IN FLORIDA.
Narrator: A BASIN IS A GEOGRAPHIC REGION
THAT CONTRIBUTES ALL OF ITS SURFACE WATER TO A RIVER SYSTEM.
THIS MAP SHOWS THE AREA FROM WHICH THE SUWANNEE RIVER GETS ITS WATER.
Dr. Graham: AND THE SUWANNEE RIVER BASIN
IS ONE OF THE LARGEST UNREGULATED RIVERS
LEFT IN THE U.S.
IT'S NOT INTERRUPTED BY DAMS OR HYDROELECTRIC POWER.
IT'S JUST ALLOWED TO FLOW FREELY IN ITS NATURAL STATE.
AND THERE AREN'T TOO MANY

RIVERS LIKE THAT LEFT IN THE U.S.
THERE IS A LOT OF FRESHWATER.
THE HIGHEST CONCENTRATION
OF FIRST ORDER SPRINGS IN THE WORLD
IT OCCURS RIGHT HERE IN
NORTH-CENTRAL FLORIDA.
THERE'S A HUGE RESERVOIR OF FRESHWATER
UNDER THE LAND SURFACE
THAT, EVEN IN TIMES OF
DROUGHT, IS EMERGING IN THE SPRINGS
AND FLOWING INTO THE RIVERS.
SO, WE DON'T GET TO THE POINT
HERE IN THIS PART OF THE STATE
WHERE WE HAVE UTILIZED
AND OVERUTILIZED THE
RESOURCE SO MUCH.
Narrator: CURRENTLY
THE SUWANNEE RIVER BASIN HAS ENOUGH WATER
TO SUSTAIN THE NATURAL ECOSYSTEM.
BUT THERE ARE
EVER-INCREASING TEMPTATIONS
TO DAM AND DIVERT THE RIVERS
TO SUPPLY WATER TO OTHER REGIONS IN THE STATE.
THERE'S A LOT OF DEVELOPMENT PRESSURE.

THERE'S A LOT OF COMPETITION
FOR THOSE WATER RESOURCES.
IF PEOPLE IN TAMPA AND MIAMI
LOOK UP TO NORTH-CENTRAL
FLORIDA
AND THINK, "HMM, YOU KNOW
"IF CALIFORNIA CAN MOVE THEIR
WATER ACROSS THE STATE
WHY DON'T WE GO AHEAD AND DO
THAT?"
SO, WE ARE INTERESTED IN
UNDERSTANDING
WHAT THE REQUIREMENTS OF
THE NATURAL SYSTEM ARE
AND ALSO UNDERSTANDING HOW
MAJOR LAND USES IN THAT BASIN
PARTICULARLY AGRICULTURE
AFFECT THE WATER QUALITY IN
THE RIVER.
Narrator:THE SUWANNEE RIVER
BASIN
FACES TWO MAJOR OBSTACLES IN
THE FUTURE --
INCREASED DEMAND AND
INCREASED POLLUTION.
AN AVERAGE 1,000 PEOPLE MOVE
INTO THE REGION DAILY
USING FRESHWATER FOR THEIR
HOMES AND SEPTIC SYSTEMS.
POLLUTION LEVELS IN THE BASIN
ARE ALSO INCREASED
WHEN FARMERS SPREAD

FERTILIZERS
HIGH IN NUTRIENTS SUCH AS
PHOSPHOROUS AND NITRATE
ON CROPS FOR INCREASED
YIELDS.
THE EXCESS FERTILIZER NOT
USED BY THE CROPS
CAN BE CARRIED TO RIVERS
CAUSING ALGAE AND OTHER
PLANTS TO GROW.
THIS CAN CHANGE WATER
QUALITY
RENDERING IT UNFIT FOR HUMAN
CONSUMPTION.
DR. GRAHAM'S TASK IS TO
PRODUCE MATHEMATICAL
MODELS
USED TO PREDICT HOW THESE
FACTORS AND OTHERS
WORK TOGETHER TO DETERMINE
THE HEALTH OF THE ECOSYSTEM.
WITH THESE MODELS
SHE HOPES TO AVOID SOME OF
THE MISTAKES
THAT WERE MADE IN THE PAST IN
FLORIDA.
Dr. Graham: WELL, THE SUWANNEE
RIVER BASIN IN FLORIDA
IS RELATIVELY UNDEVELOPED
AS OPPOSED TO SOUTH FLORIDA
WHICH WAS HEAVILY DEVELOPED
IN THE 1950s

AFTER THE HUGE DRAINAGE PROJECT
THAT BASICALLY DRAINED THE EVERGLADES
AND CREATED AGRICULTURAL LAND AND URBAN LANDS
FOR PEOPLE TO LIVE ON.
BUT 20, 30 YEARS AFTER THAT PROCESS
PEOPLE STARTED DISCOVERING
THE HARM THAT IT WAS DOING
TO THE EVERGLADE SYSTEMS.
Narrator: OVER THE LAST 100 YEARS
THE EVERGLADES HAVE BEEN
SYSTEMATICALLY DAMMED AND PUMPED
FOR AGRICULTURAL AND URBAN DEVELOPMENT.

40% OF FLORIDA'S RESIDENTS
CURRENTLY LIVE IN THE AREA.
AND CROPS GROWN HERE
SUPPLY HALF OF THE WINTER VEGETABLES
SOLD IN THE UNITED STATES.
BUT THE COST TO THE ENVIRONMENT HAS BEEN ASTONISHING.
BECAUSE OF OVERDEVELOPMENT
THE FLOW OF FRESHWATER HAS DRAMATICALLY DECREASED

AND EXCESS NUTRIENTS FROM
FARMS AND RANCHES
HAVE CHANGED THE ECOSYSTEM
TO THE POINT WHERE THE
REGION IS SAID TO BE
ON THE VERGE OF BIOLOGICAL
COLLAPSE.
SO, WHAT WE WOULD LIKE TO DO
IS UNDERSTAND THE NEEDS OF
THE NATURAL ECOSYSTEM
AS WELL AS THE NEEDS OF
HUMANS
AS WELL AS THE NEEDS OF
AGRICULTURE
SO THAT WE DON'T PASS THAT
TIPPING POINT
AND HAVE TO SPEND $8 BILLION
RESTORING THE SUWANNEE
RIVER BASIN
LIKE WE'RE HAVING TO DO IN THE
EVERGLADES.
Narrator: TO PREDICT THE FUTURE
OF THE SUWANNEE RIVER BASIN
SCIENTISTS FIRST HAVE TO
UNDERSTAND
HOW IT IS PRESENTLY
FUNCTIONING.
DR. JOHN MARTIN IS A
COLLEAGUE OF PROFESSOR
GRAHAM'S
AT THE UNIVERSITY OF FLORIDA
WATER INSTITUTE.

HIS TEAM STUDIES THE HEALTH
OF THE SUWANNEE RIVER BASIN
SAMPLING AND TESTING ITS
WATER FOR SIGNS OF POLLUTION.
BECAUSE OF SANDY SOILS
AND THE SOLUBLE
LIMESTONE-BEDROCK GEOLOGY
IN THIS PART OF FLORIDA
RIVERS HERE RUN ABOVE
GROUND
AND THEN FLOW UNDERGROUND
THROUGH SINKHOLES.
ABOVE GROUND, WATER CAN BE
SAMPLED DIRECTLY.
BUT UNDERGROUND
THE WATER FILLS AND MOVES
THROUGH THE POROUS ROCK
AQUIFER.
THIS WATER CAN BE ACCESSED
THROUGH A SERIES OF WELLS.
THE AQUIFER WATER HERE
THE WATER THAT'S CONTAINED IN
THE ROCKS
IN THE VERY SMALL,
MICROSCOPIC, PORE SPACES
WITHIN THE ROCK
IS WHAT'S UTILIZED FOR
DRINKING WATER
AND, ACTUALLY, ALL WATER
SO AGRICULTURE-IRRIGATION
WATER, BOTTLING WATER
ANY KIND OF WATER USAGE IS

ALMOST ALL FROM GROUND WATER.
Narrator: BY CAREFULLY MEASURING THE DEPTH OF GROUND WATER
MARTIN'S TEAM CAN CALCULATE HOW MUCH IS BEING USED.
17.29.
THEY ALSO RECORD THE WATER'S CHEMICAL COMPOSITION
TO DETERMINE NUTRIENT LEVELS THAT COULD ADVERSELY AFFECT THE HEALTH OF THE WATER.
OKAY, WE'RE READY TO SAMPLE.
Narrator: ONE KEY NUTRIENT THEY SAMPLE FOR IS NITRATE.
ACTUALLY, NITRATE IS REGULATED IN DRINKING WATER STANDARDS
BY THE ENVIRONMENTAL PROTECTION AGENCY.
THERE'S BEEN MONITORING OF THE NITRATE LEVELS
IN SOME OF THE SPRINGS AROUND HERE FOR DECADES.
AND THE NITRATE LEVELS HAVE BEEN SHOWN TO BE INCREASING OVER THAT TIME.
Narrator: IF NITRATE LEVELS CONTINUE TO RISE
ALGAE WILL CONTINUE TO FLOURISH

CREATING NETS THAT PREVENT LIGHT
FROM REACHING PLANTS LIVING IN THE WATER.
IF THESE PLANTS ARE LOST
THE OXYGEN THEY PRODUCE
WILL ALSO BE LOST
RESULTING IN AN ANOXIC ENVIRONMENT.
THIS CAN CAUSETHE DEATH OF ANIMALS
AND BENEFICIAL ORGANISMS
LIVING IN THE WATER
RENDERING THE WATER
UNUSABLE FOR HUMAN CONSUMPTION.
THIS IS NOT NATURAL,THE ALGAE.
THIS IS ALL ALGAE THAT COMES
FROM HIGHER NUTRIENT LEVELS
THAN THERE SHOULD BE IN THIS WATER.
THERE SHOULDN'T BE ANY ALGAE
GROWING HERE AT ALL.
I MEAN, I'VE NEVER SEEN IT THIS BAD.

I MEAN, THIS IS REALLY KIND OF DISGUSTING.
YOU CAN SEE IT ALL ALONG THE BANKS HERE.

NITRATE COMES FROM

FERTILIZER, PREDOMINANTLY --
FERTILIZER AND ANIMAL WASTE,
INCLUDING HUMAN WASTE.
BUT THERE'S A LOT OF
AGRICULTURE AROUND HERE
SO THEY FERTILIZE THEIR CROPS
AND IT RUNS OFF THROUGH THE
SURFACE WATER
INTO THE GROUND WATER AND
THEN COMES OUT HERE.

YOU WANT ANOTHER ONE, OR IS
THAT...
THE WHOLE AREA IS HIGHLY
AGRICULTURAL
SO THERE ARE CATTLE FEED
LOTS, POULTRY FARMS, ROW
CROPS.
THE CATTLE PROVIDE ANIMAL
WASTE, WHICH ARE
HIGH-NUTRIENT LOADS
AND ROW CROPS PROVIDE A LOT
OF NITROGEN
THAT'S NOT A NATURAL SOURCE
OF NITROGEN, THROUGH
FERTILIZATION.
Moore: HUMAN ACTIVITIES
BASICALLY CAN DEGRADATE THE
RIVER TO THE UNSEEN EYE,
RIGHT?
TO THE NAKED EYE, YOU JUST
LOOK --

IT'S A PRETTY RIVER, IT FLOWS, IT DOES ITS THING
BUT WHAT'S GOING ON CHEMICALLY?
AND JUST LIKE IF YOU GO OUT TODAY
YOU CAN GO OUT THERE AND SEE THE DUCKWEED AND THE ALGAE
AND THESE ARE THINGS
THAT HISTORICALLY HAVE NOT BEEN THERE.
WELL, BASICALLY, WHAT YOU HAVE HAPPEN
IS IF YOU GET TOO MUCH OF A BIOMASS IN THERE
THEN YOU CAN START DESTROYING THE WATER THAT WAY.
Narrator: INCREASED NUTRIENT LEVELS
ARE A CONCERN FOR WATER BASINS WORLDWIDE.
BUT THE UNIQUE GEOLOGY OF THE LANDSCAPE HERE
MAKES THE DANGER ALL THE GREATER.
THE GEOLOGY OF THIS AREA IS KNOWN AS KARST.
BELOW THE SOIL LAYER
LIES LIMESTONE DISSOLVED BY RAINWATER.
THIS DISSOLUTION OF ROCK

CREATES AN UNDERGROUND SYSTEM OF CAVES AND POROUS ROCKS
THAT ALLOW WATER AND THE POLLUTION THAT IT'S CARRYING TO MOVE RAPIDLY.
FLOW IN KARST SYSTEMS IS VERY RAPID
BECAUSE IT HAS THESE CAVES OR CONDUITS
THAT ESSENTIALLY HAVE INFINITE PERMEABILITY.
THERE IS NO RESISTANCE TO WATER FLOW.
Dr. Graham: AND THERE'S VERY LITTLE BIOLOGICAL ACTIVITY
THAT WOULD REDUCE NITRATE LEVELS
AND THAT'S ONE OF THE CONCERNS.
IF YOU HAVEA TYPICAL RIPARIAN ZONE
OR A SORT OF SANDY SUPERFICIAL AQUIFER FEEDING A RIVER
THERE'S LOTS OF BIOLOGICAL ACTIVITY ALONG THE RIVERBANKS.
BUT THESE SPRINGS ARE JUST COMING OUT
IN SORTOF HOLES IN THE ROCK
AND THERE'S NO BIOLOGICAL

REMEDIATION THAT HAPPENS.
Narrator: IN A TYPICAL WATER BASIN
WATER MOVES SLOWLY THROUGH SOIL LAYERS
CONTAINING A VAST ARRAY OF BIOLOGICAL ORGANISMS
THAT HELP TO REMEDIATE EXCESS NUTRIENT LOADING.
BUT BECAUSE OF THE GEOLOGY OF THIS REGION
WATER AND DISSOLVED NUTRIENTS MOVE QUICKLY TO THE AQUIFER
WITH LITTLE CHANCE FOR REMEDIATION.
AND A SECOND FEATUREOF THIS LANDSCAPE
POSES AN EVEN GREATER RISK.
UNDERGROUND CAVES CAN COLLAPSE
CREATING SINKHOLES THAT ARE A DIRECT CONNECTION
BETWEEN NUTRIENT RUN OFFAND DRINKING WATER.
Dr. Clark: ONE OF THE CRITICAL ASPECTS ABOUT THESE DIRECT CONNECTIONS
THAT SINKHOLES PROVIDE BETWEEN THE SURFACE AND THE AQUIFER
IS THAT IF THERE'S ANY KIND OF

POLLUTANTS OR CONTAMINANTS
THAT ARE ASSOCIATED WITH
THAT WATER
THAT WATER'S NOW GOING
DIRECTLY INTO THE AQUIFER
DIRECTLY INTO THE GROUND
WATER.
SO, IT'S REALLY THESE
SINKHOLES
ARE A DIRECT CONNECTION
BETWEEN POTENTIAL
CONTAMINANTS
THAT WE MIGHT APPLY TO THE
SURFACE
AND OUR DRINKING WATER
SUPPLY.
AND IN THE CASE OF NITRATES IN
THE GROUND WATER
IT REALLY HAS TO DO
WITH SOMETHING WE'RE DOING
UP ON TOP OF THE SOIL
WHERE IT MAY BE
AN INAPPROPRIATE AMOUNT OF
FERTILIZER BEING APPLIED
OR MAYBE IN A DIFFICULT AREA
TO TRY TO CONTROL THAT.
Narrator: THE PROBLEM
OF IDENTIFYING SPECIFIC
SOURCES OF POLLUTANTS IN THE
BASIN
IS COMPLICATED.
BY USING DATA GATHERED FROM

FIELD RESEARCH
TO BUILD COMPUTER MODELS
DR. GRAHAM AND HER
COLLEAGUES
CAN PREDICTOVERALL FUTURE
TRENDS.
WHAT IS CLEAR IS THAT IF THE
POPULATION KEEPS INCREASING
AND NUTRIENT LEVELS IN THE
WATER INCREASE
THEN THE WATER IN THE
SUWANNEE RIVER BASIN
WILL NOT BE FIT FOR HUMAN
CONSUMPTION.
HOWEVER, IF LAND USE IS
CHANGED AND POLLUTION
LEVELS DECREASE
GRAHAM'S MODELS PREDICT
MORE POSITIVE OUTCOMES.
Dr. Graham: WHAT WE'RE TRYING
TO DO WITH OUR MODELS
IS FILL THE GAPS BETWEEN OUR
OBSERVATIONS.
WHEN WE OBSERVE THE
ENVIRONMENT, WE'RE ONLY
SEEING
THE CONSEQUENCES OF WHAT
ALREADY HAPPENED
AND WE HAVE NO CONTROL OVER
THAT.
SO, MODELS ALLOW US TO TAKE
THAT UNDERSTANDING

AND PROJECT IT INTO THE
FUTURE AND PROVIDE
INFORMATION
TO PLANNERS AND DECISION
MAKERS
ABOUT HOW OUR ACTIONS
AFFECT WATER QUALITY
AND THE FLOW OF WATER
THROUGH OUR ENVIRONMENT.
WHAT I WOULD ENVISION IS
LOOKING
AT ALTERNATIVE-IRRIGATION
PRACTICES
ALTERNATIVE-FERTILIZATION
PRACTICES
ALTERNATIVE-CULTURAL
PRACTICES THAT KEEP MOST OF
THE NUTRIENTS
IN THE ROOT ZONE, WHERE THE
PLANT CAN USE THEM.
ON A WATERSHED BASIS
THERE ARE MORE VULNERABLE
AND LESS VULNERABLE
AREAS OF LANDSCAPE.
IF YOU WANT TO GROW CORN IN
YOUR WATERSHED
THERE WILL BE BETTER PLACES
TO GROW CORN
AND WORSE PLACES TO GROW
CORN.
IF YOU WANT THIS MANY PEOPLE
IN YOUR WATERSHED

THERE ARE BETTER PLACES TO HAVE URBAN CENTERS THAN OTHERS.
SO, I THINK IT'LL BE A BALANCING ACT
BUT WHAT WE HOPE TO DO
IS BE ABLE TO UNDERSTAND THE TRADE-OFFS
BECAUSE TO HAVE NO IMPACT, THERE WOULD HAVE TO BE NO HUMANS.
AND THERE'S NO OPTIMUM SOLUTION
BUT THERE'S A SORT OF A TRADE-OFF CURVE
WHERE, IN THE END, PEOPLE HAVE TO DECIDE
WHAT KIND OF WORLD THEY WANT TO LIVE IN.

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