Sustainable Water Integrated Management - Support Mechanism (SWIM- SM)

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

Project funded by the European Union

STUDY TOUR ON WASTEWATER MANAGEMENT
USING NATURAL TREATMENT SYSTEMS (NTS) IN RURAL AREAS

NTSs, their history, advantages, disadvantages, geographical coverage, and their use

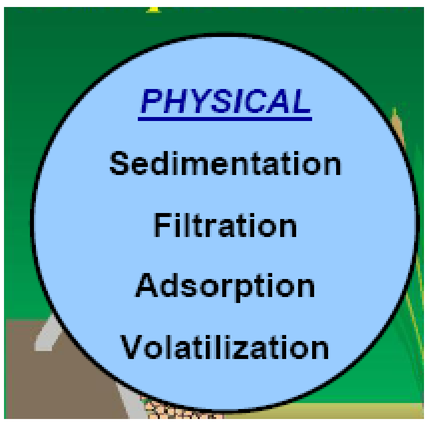
CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

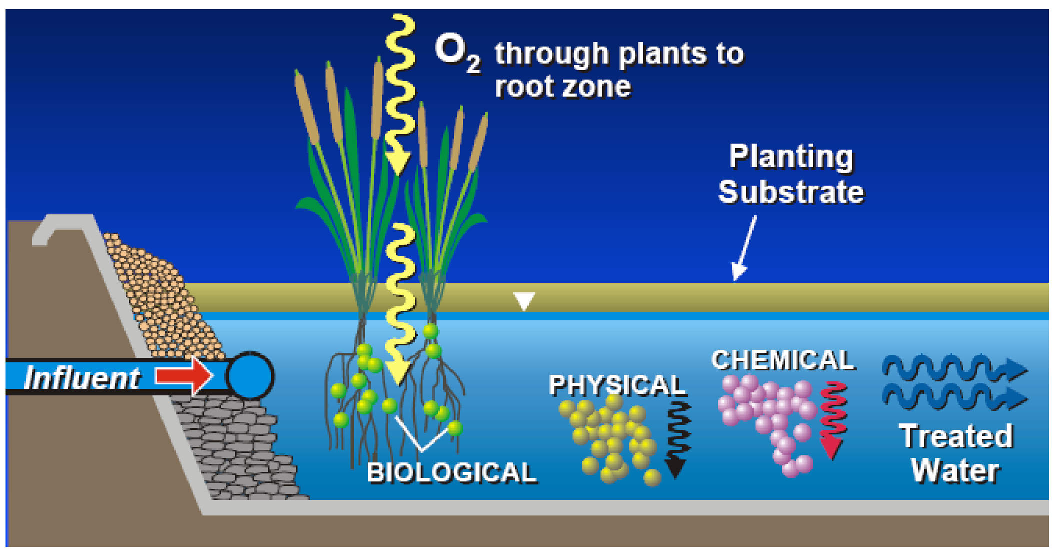
Salvatore Barbagallo, Giuseppe L. Cirelli ,
Alessia Marzo, Mirco Milani, Attilio Toscano

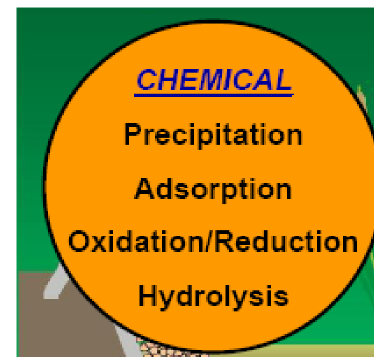
Catania, (Italy) 27 July 2015

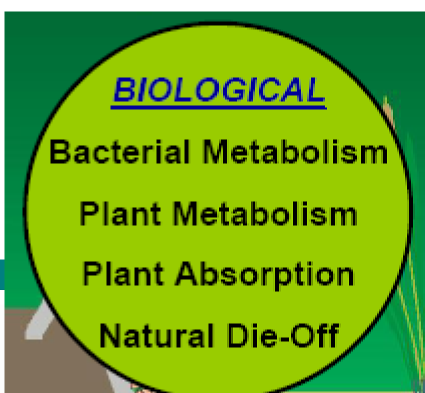
Natural treatment systems

- In the natural environment, physical, chemical, and biological processes occur when water, soil, plants, microorganisms, and the atmosphere interact. Natural treatment systems are designed to take advantages of these processes to provide wastewater treatment
- The processes involved in natural systems include many of those used in mechanical or conventional systems (sedimentation, filtration, gas transfer, adsorption, ion exchange, chemical precipitation, chemical oxidation and reduction, and biological conversion and degradation) as well as other unique to natural systems such as photosynthesis, photooxidation and plant uptake.



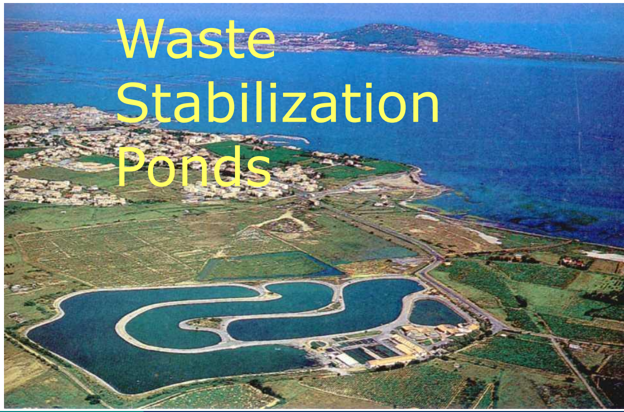






Natural treatment systems

- The EPA (Environmental Protection Agency of United States) defines natural treatment systems as those having minimal dependence on mechanical elements to support the wastewater treatment process. Instead, the systems use plants and bacteria to break down and neutralize pollutants in wastewater
- These techniques are popularly described as “green”, “environmentally friendly” and “sustainable” and included:
  - Wastewater storage reservoir
  - Constructed wetland
  - Waste Stabilization Ponds



Wastewater storage reservoir (WRS)

- Wastewater storage reservoir (WSR), also called wastewater stabilization reservoirs, have been operated for more than 30 years for the storage of wastewater effluents during the wet winter months
- **the main objective** of wastewater storage reservoirs was initially seasonal regulation, so that peak (daily or seasonal) **irrigation demand** in excess of average water availability could be met. However, experience soon demonstrated that, aside from **regulation**, storage plays an important role in the **treatment**
- The first experiences of wastewater storage in very large system have been carried out in Israel since the '70s (more than 200 reservoirs with capacity of up to tens of millions of m^3). More recently wastewater storage reservoirs have been built in Jordan, Morocco, Spain, France and other Mediterranean countries (Barbagallo et al., 2001). Several examples of wastewater stabilization for reuse have been put in operation also in U.S.A., Canada, Australia.
- Nowadays, as wastewater reuse in agriculture has experienced a great success, storage reservoirs have become a common feature of rural landscapes: in fact, especially in the case of small reuse systems, **storage facilities allow to achieve the quality standards required for irrigation**, while making reuse economically possible.

Wastewater storage reservoirs

- Wastewater storage can be also applied in those situations :
  - **Coastal areas:** Wastewater is stored during the summer in order to avoid the contamination of beaches during the tourism season. By the end of summer wastewater will be released from the reservoirs into the sea. Meanwhile, these effluents will reach excellent quality due to long residence time within the reservoirs during the summer months
  - **River/stream recovery (I):** Wastewater is stored during the dry season when the river runs at minimum flow. Wastewater of high quality will be released from the reservoirs to the river when river-flow is at maximum, thus obtaining maximum dilution and minimum negative ecological impact.
  - **River/stream recovery (II):** Wastewater is stored when river-flow is at maximum. Wastewater of very high quality is then released from the reservoirs to the river during the dry period as a substitute for freshwater, in order to avoid total drying of the river and ecosystem destruction
  - **High quality effluents are required**. Wastewater contains not only organic matter but also significant concentrations of pathogens, heavy metals, hard detergents, pesticides, organic micro-pollutants and other pollutants which are not removed by the classic sewage treatment plants. Stabilization reservoirs are able to remove most of them
  - **Cooling water:** Wastewater is more and more used as cooling water in power stations and other installations. Wastewater storage reservoirs can supply cooling towers with wastewater of proper quality and temperature in due time.

Constructed wetlands

- Constructed Wetlands for the purpose of treating water have a shorter history. The worldwide spread of this technology originated from research conducted at the Max Planck Institute in West Germany, starting in 1952 (Bastian and Hammer, 1993).
- The first full-scale Constructed Wetland into operation in 1974 in Liebenburg-Othfresen, Germany, for treatment of municipal wastewater (Kickuth, 1977). But only in the 1990s, the technology had become a preferred method for wastewater treatment for small villages and other decentralized wastewater applications. This was thanks Directive 91/271/EEC, concerning urban waste water treatment, where the method of wetland is mentioned as the approach to be used for small and medium settlements
- Today Constructed Wetlands are being used worldwide to treat just about any wastewater imaginable, including that from mines, animal and fish farms, highway runoff, industry of all types, and municipal and domestic sewage (Vymazal, 2002).
- Different types of Constructed Wetlands have been developed
  - Surface flow (SF) or free water surface (FW)
  - Subsurface horizontal flow (HSSF, HF)
  - Vertical flow (VF)

Constructed wetlands

- Wetlands can be also applied in those situations :
  - **wildlife habitat purposes**. wetlands are constructed close to estuarine waters for creating appropriate environmental conditions to encourage the established of animal and wetland plant species
  - **flood control**. wetlands, called buffer strips, function like natural tubs, storing flood waters that over-flow riverbanks and surface water that collects in depressional areas. In this way, wetlands can help protect adjacent and downstream property from flood damage
  - **Aquaculture**. Wetlands are constructed to be used for production of food and fiber.

Waste Stabilization Ponds (WSP)

- Waste Stabilization Ponds (WSP), also called lagoons, have been employed for treatment of wastewater for over 2,000 years.
- The first recorded construction of a pond system in the U.S. was in San Antonio, Texas, in 1901 (Gloyna,1971).
- Today (Mara, 2003, US EPA 2011) :
  - over 8,000 wastewater treatment ponds (comprising more than 50 percent of the wastewater treatment facilities) are in place in the United States
  - 2500 in France
  - 1100 in Germany
  - 39 in UK
  - Larger pond systems are in place in New Zealand, Australia and Africa
- They are used to treat a variety of wastewaters, from domestic to complex industrial effluent, and they function under a wide range of climatic conditions, from tropical to arctic.
- Ponds can be used alone or in combination with other wastewater treatment processes
- Different types of ponds have been developed
  - Anaerobic
  - Facultative
  - Maturation

Main features of natural wastewater treatments

- Although each type has its own distinct way to process the waste, they have many advantages in common:
  - ***Simplicity***: plants design and construction are very simple. Even small building companies can build them and unqualified staff can carry out their maintenance operations.
  - ***Cost-effectiveness:*** plants require low building, labour and maintenance costs. They are much more convenient than the conventional (biological) wastewater plants during the operational phase, because they require almost no energetic consumption or waste treatment. Mechanical devices are not used in these treatments, thus reducing the maintenance costs. The only limiting factor is the availability and the cost of land to place the treatment plants.
  - ***Efficiency:*** natural wastewater treatment plants are generally rather efficient for the removal of most of the pollutants. The efficiency is highly dependent on climatic conditions: it is lower with low temperatures.
  - ***Reliability:*** natural systems are very reliable even in extreme operating conditions. They can adsorb a wide variety of hydraulic and organic feed.

Disadvantages of natural wastewater treatments

- The disadvantages of natural wastewater treatments are:
  - The surface requirements are high compared with those of conventional technical treatment technologies (cost and availability of suitable land).
  - the need for a preliminary treatment before the wastewaters treated by the system
  - the need of higher retention time than a conventional system
  - Mosquitoes and other insects can breed if vegetation is not controlled
  - If not designed properly may cause odour problem

Use of natural system around the world

NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

EUROPE

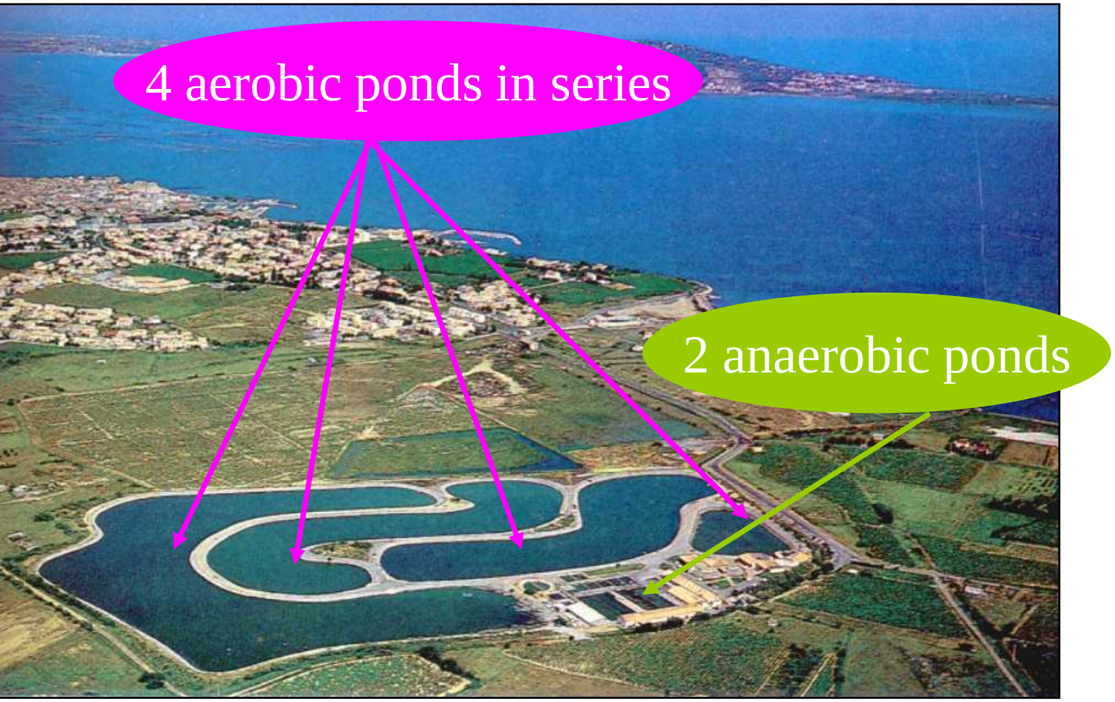
NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

CW in Jesi city (Italy)

- PE: 60.000 (designed)
- Flow rate: 19.000 m^3/day
- 12 ha

Waste Stabilization Ponds



Waste Stabilization Ponds system to secondary and tertiary treatment 20.000 PE in Mezé (France)

France: constucted wetland "in series"

Total Area: 8.400 m^2

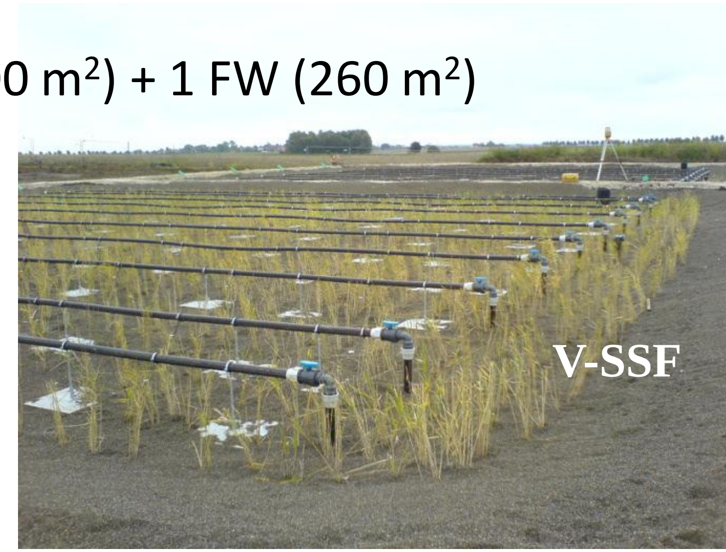
Denmark: Free water surface CW for tertiary treatment

Denmark: Rudkøbing city

Germany: Berel village

- urban wastewater treatment
- P.E.:700
- Constructed wetland system: 2 V-SSF (1.200 m^2) + 1 FW (260 m^2)

	Influent	Effluent
CSB	369 mg/l	43 mg/l
BSB5	209 mg/l	8 mg/l
NH4-N	55 mg/l	3 mg/l
NO3-N	3 mg/l	4 mg/l
Nges.	n. b.	7 mg/l
Pges.	12 mg/l	3 mg/l



(Foto: Ingenieurbüro Blumberg)

Cina: Jiangsu

- urban wastewater treatment
- Constructed wetland system: V-SSF (490 m^2) + H-SSF (100 m^2) + lagoning (400 m^2) + reed bed for sludge dewatering (100 m^2)
- Flow rate: 50 m^3/day

Parameter (mg/l)	COD	BOD5	TN	NH-3N
Inflow	178	63	91	54
Outflow ST	43	10	38	28
Outflow VF	14	1	20	3
Outflow HF	15	1	20	1
Pond	18	2	16	0.5
Outflow (riparian wetland)	28	5	6	0.7
Efficiency (%)	84	93	94	99

Ireland
FWS CW for farm runoff

Bornem, Belgium
stormwater runoff

Floating mats of emergent plants


Ingstrup, Denmark, dairy farm
Photo Hans Brix


HF CW Estarreja, Portugal
aniline and HNO_3 wastewaters

HF CW London Heathrow, de-icing and runoff waters


Zero discharge willow CW
Vravej, Denmark


Hybrid CW at Oaklands
Park, UK (5/1990)
Photo Paul Cooper

VF-HF CW, Leiria, Portugal
landfill leachate


VF-VF-HF CW, France
leachate from composting site
Photo Georges Reeb

North America

NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

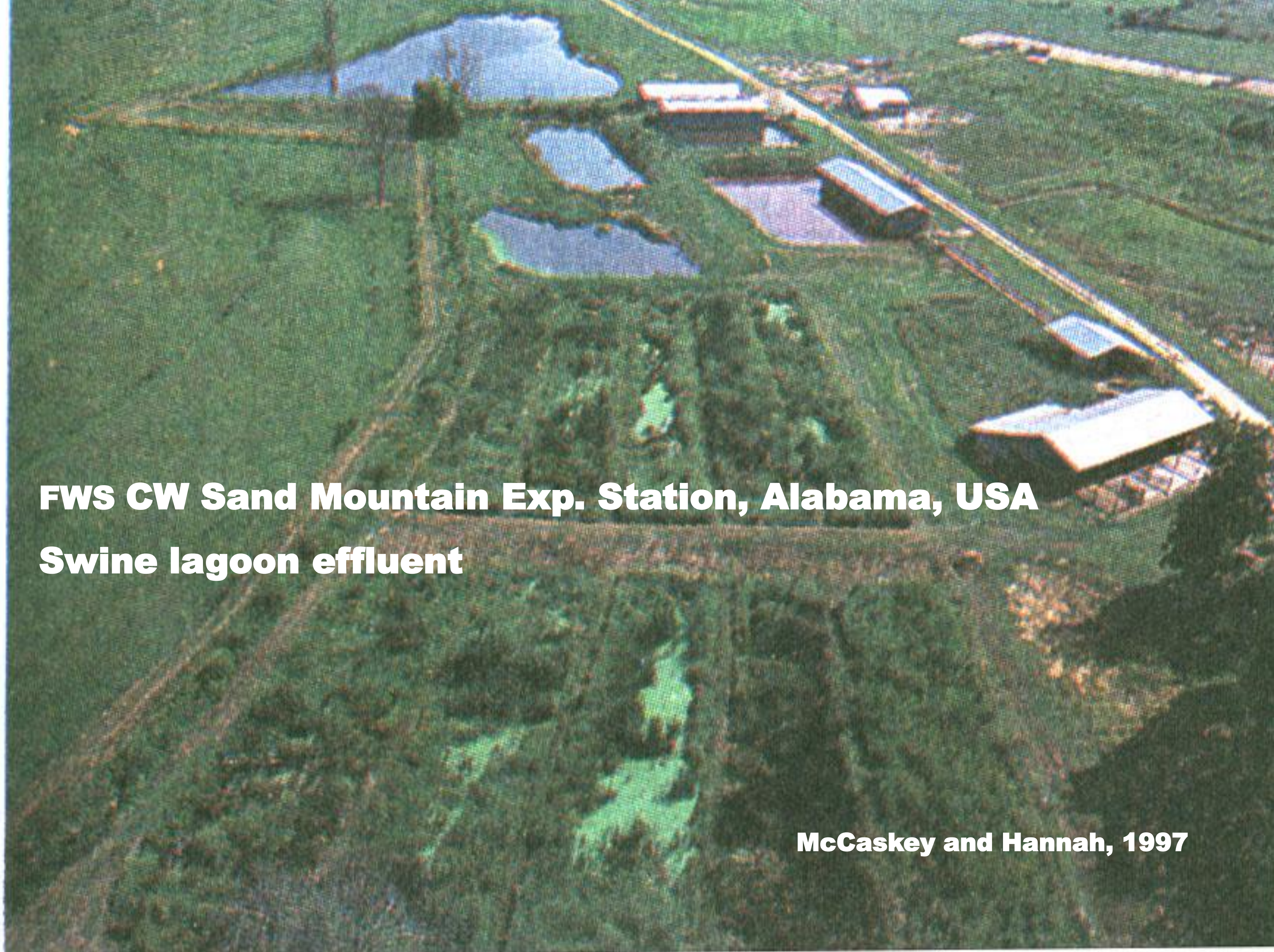

Monastery Run, Pennsylvania
Alkaline mine drainage

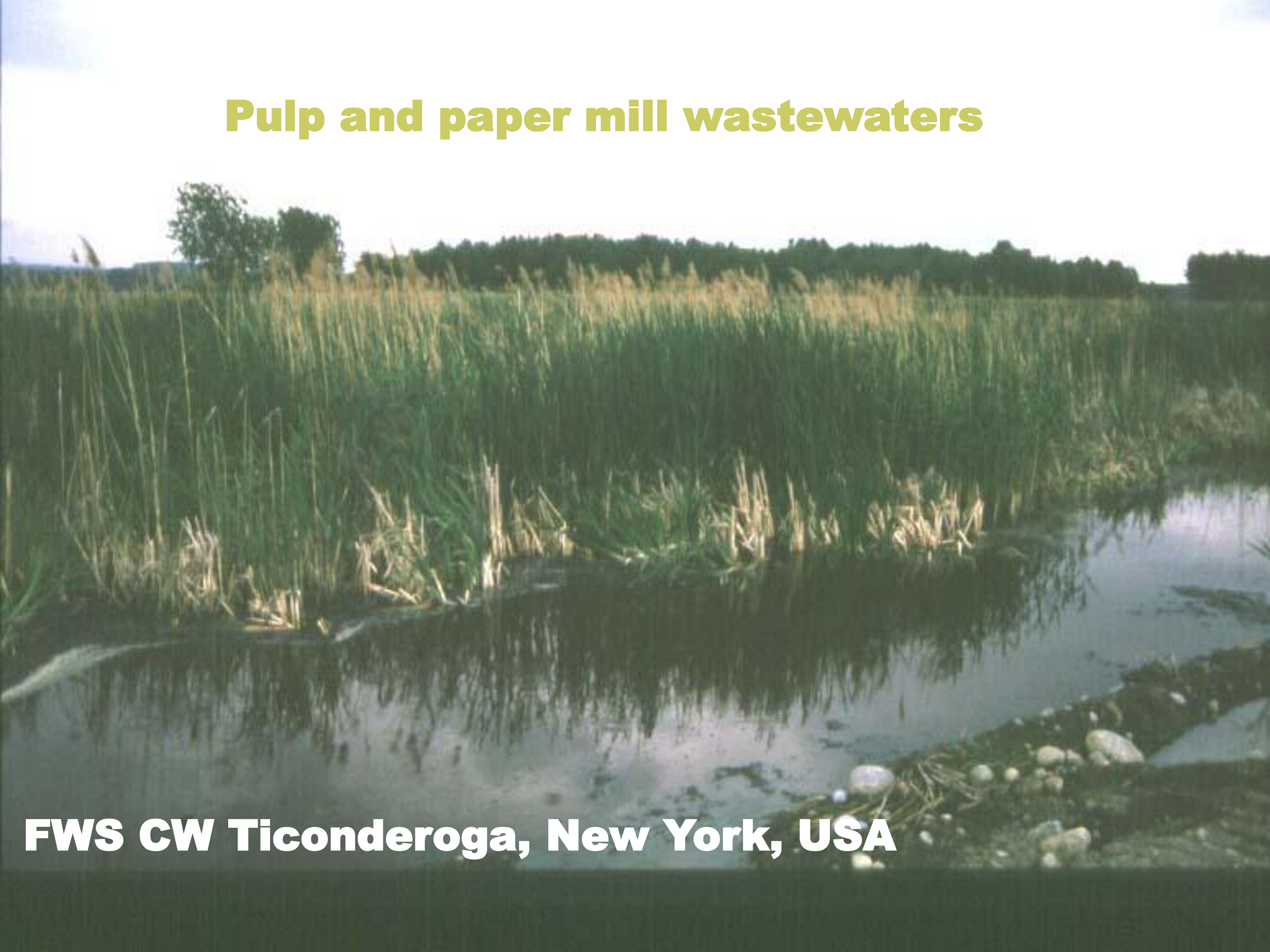

FWS CW Carbondale, Ohio
Acid mine drainage


Western Pennsylvania
Acid mine drainage (removal of Al)


Rivertown, South Carolina, USA
golfcourse runoff


Parking lot stormwater runoff
Charleston, South Carolina


FWS CW Sand Mountain Exp. Station, Alabama, USA
Swine lagoon effluent
McCaskey and Hannah, 1997


Pulp and paper mill wastewaters
FWS CW Ticonderoga, New York, USA

HF CW Wilmington, North Carolina, USA

District of Columbia wastewater treatment system

Palm Beach, Florida: Wakodahatchee Wetlands

- 56 acres to tertiary treatment (aquifer recharge)
- Over 140 different birds species

South America

NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria


Nativa I, Uruguay,
HF CW, soft drink facility
wastewaters (2001)
Courtesy Silvana Perdomo

Nativa II, Uruguay

2 ha FWS

Treatment of soft drink facility wastewaters

Courtesy: Silvana Perdomo

Mallarino Dairy Farm, Uruguay, FWS-VF CW

Courtesy: Silvana Perdomo

Australia, New Zealand, Oceania

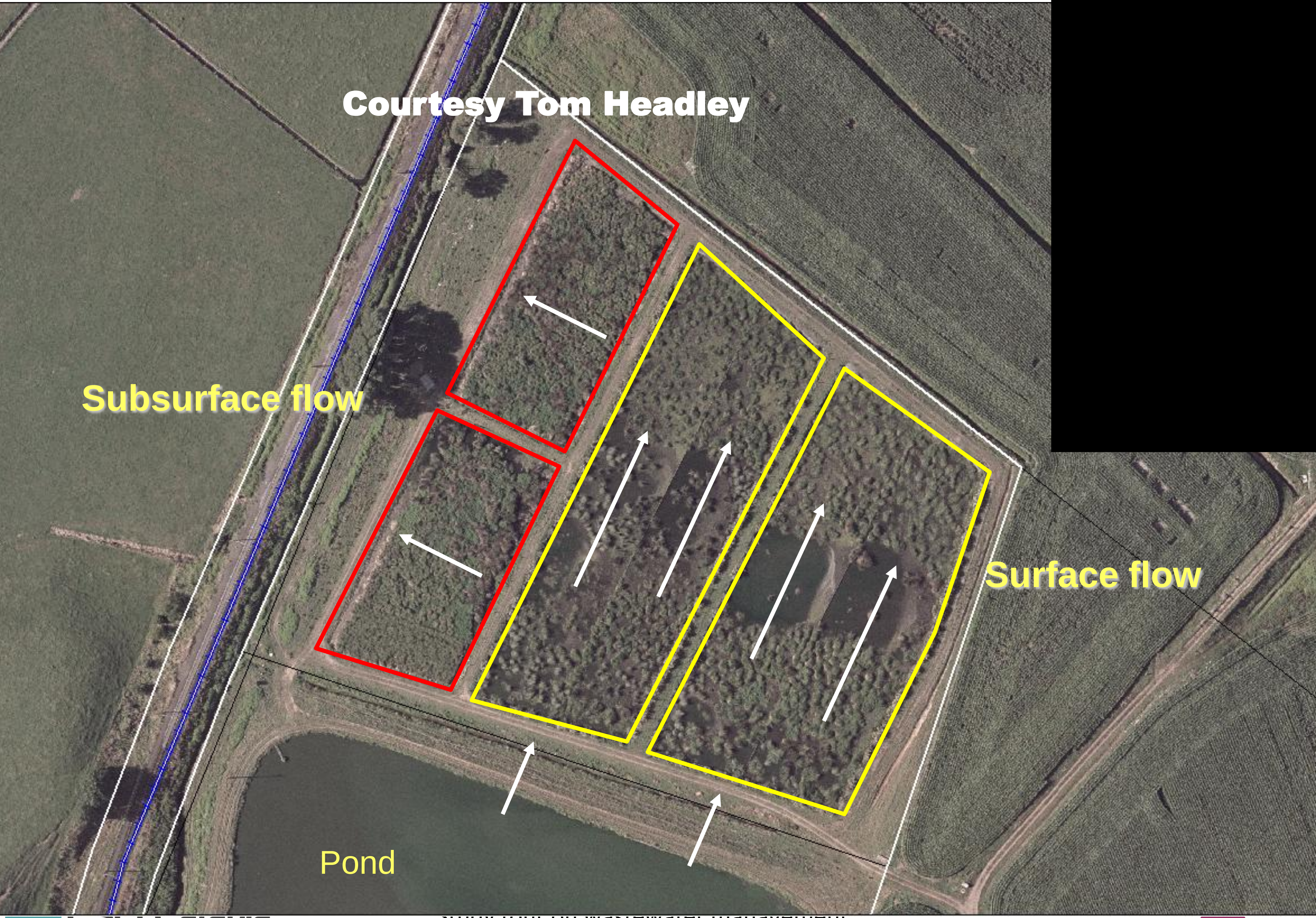
NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

FWS CW Plumpton Park, NSW, Australia Stormwater runoff


Bonnyrigg Park, Fairfield, NSW, Australia
Stormwater runoff

HF CW The Channon, NSW, Australia
laundry wastewaters


Courtesy Tom Headley
Subsurface flow
Surface flow
Pond


Courtesy
Tom Headley
FWS CW BogBurn
New Zealand (South Island)
Pasture runoff

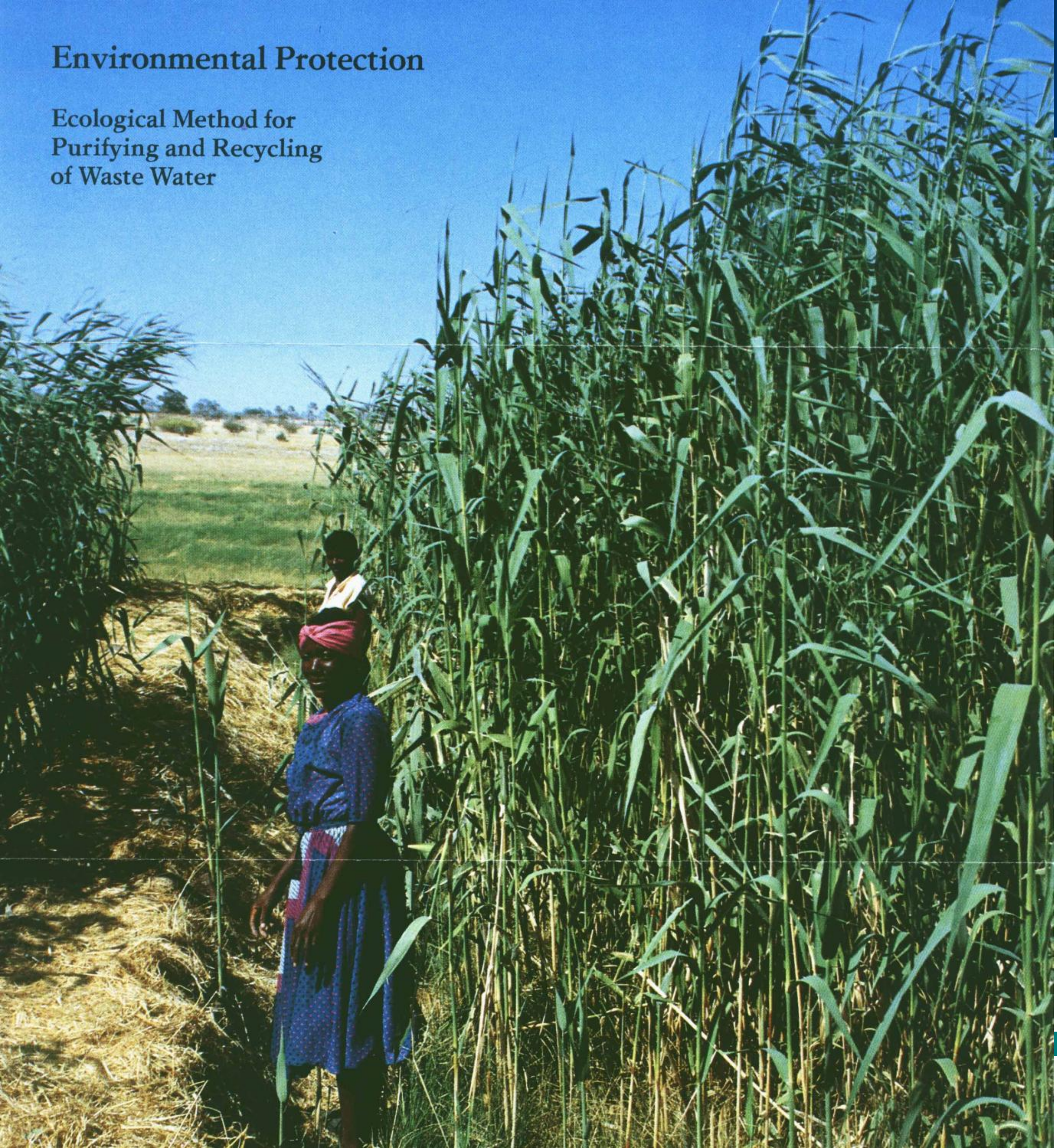
FWS CW Lake Okaro, New Zealand, pasture runoff

Upper photo courtesy Tom Headley

Africa

NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria



HF CW Anandjokwe, Namibia

Hospital wastewaters

1988


HF CW Kasese, Uganda
Acid mine drainage
Courtesy: Frank Kansiime


HF CW Kasese, Uganda
Acid mine drainage
Courtesy: Frank Kansiime
18 2 2003

Asia

NTSs, their history, advantages, disadvantages, geographical coverage, and their use

CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

China: Shenyang (the most populous city in Northeast China)

- urban wastewater treatment + stormwater treatment
- PE: 6.000
- Construct wetland system: 3 V-SSF+ 1 FWS
- Area: 8.000 m^2

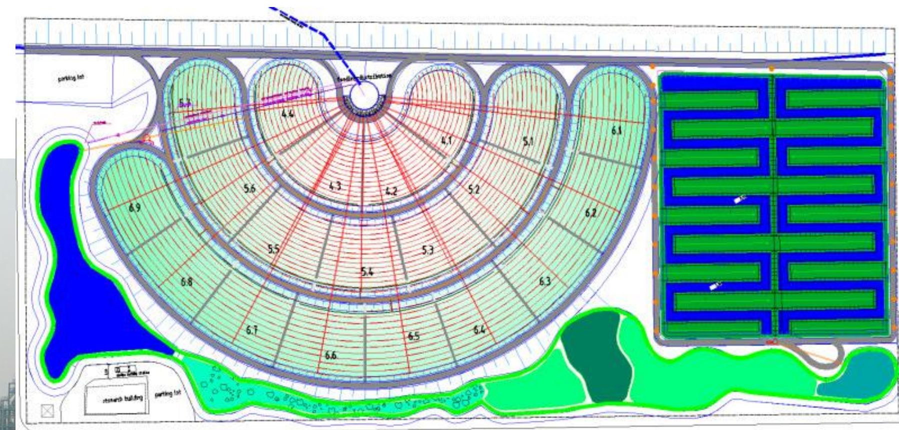
(Foto: Ingenieurbüro Blumberg)

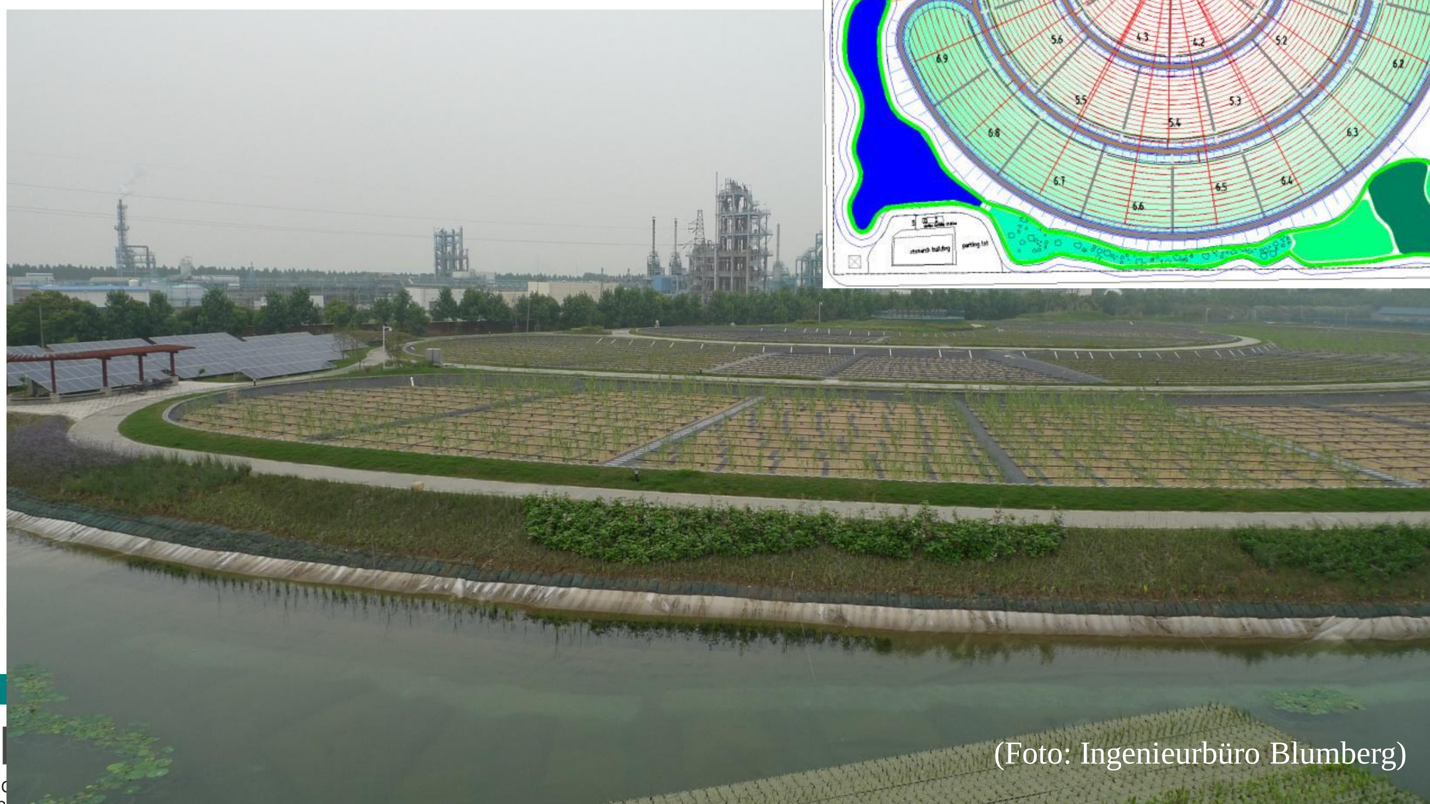
China: Beijing city

- Area 8 ha
- over 300 plant species
- Photo: Beijing Tsinghua Urban Planning & Design Institute

China: Changshu city

- industrial wastewater treatment + wastewater reuse + Yangtze River protection
- flow rate: 4.000 m^3/day
- Area: 6 ha
- Constructed wetland: VSSF (20.000 m^2) + FW (7.500 m^2)+ H-SSF (10.000 m^2)



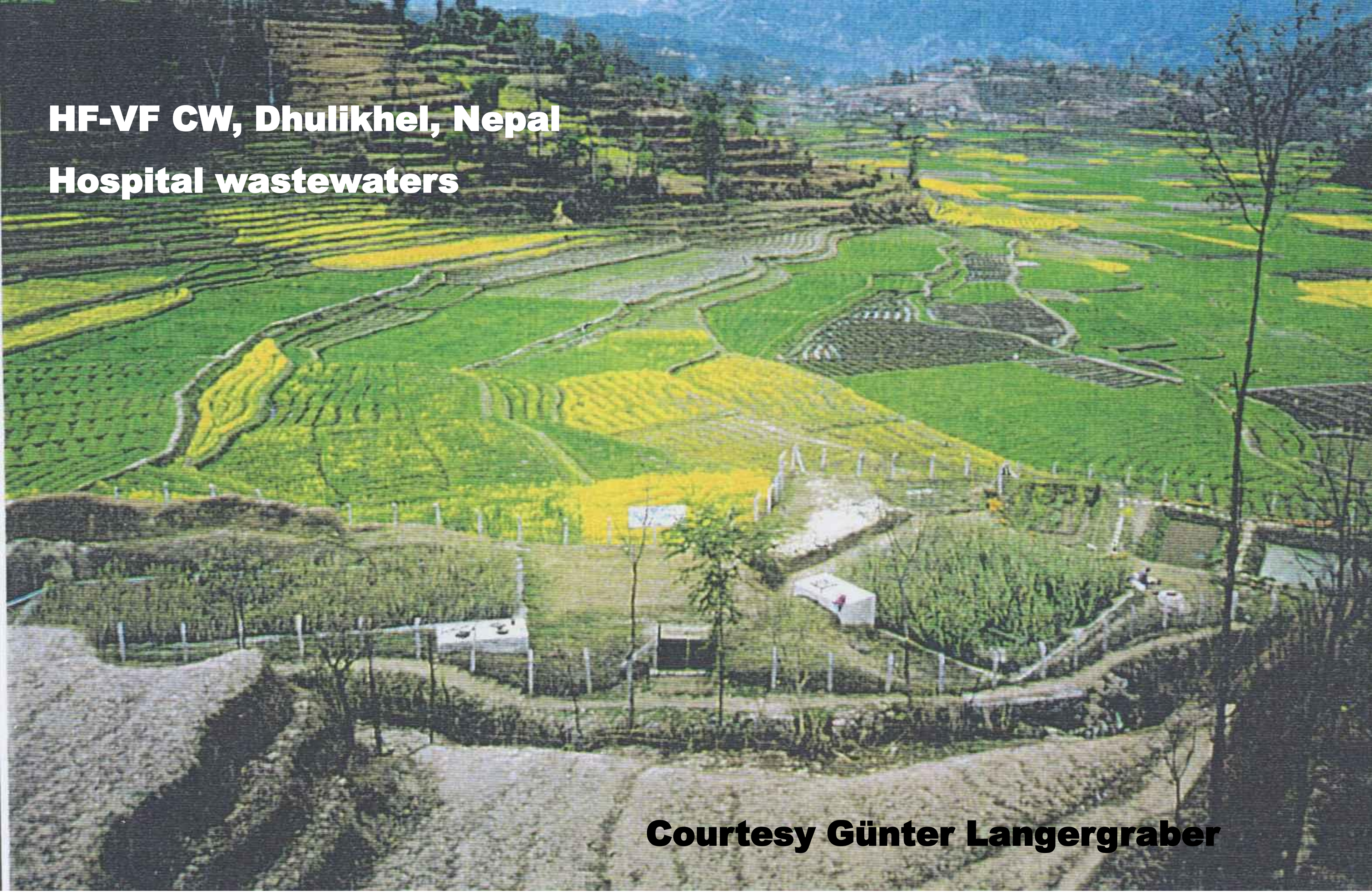


(Foto: Ingenieurbüro Blumberg)

FWS-HF CW Yantian, P.R. China, industrial wastewaters

HF-VF CW, Dhulikhel, Nepal

Hospital wastewaters



Courtesy Günter Langergraber

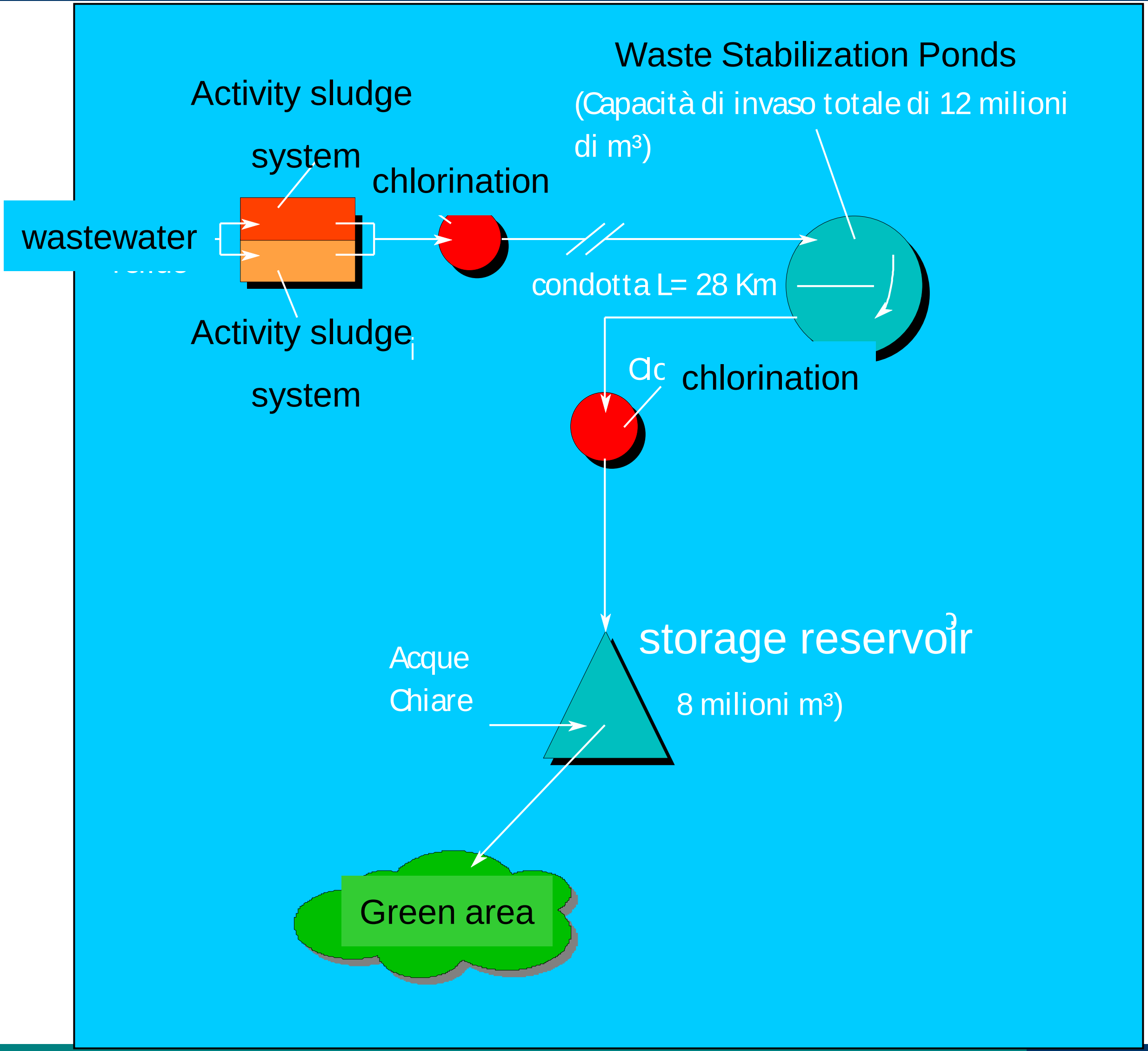
HF CW Nimr, Oman **petroleum contaminated waters**

Source: www.image.dk/-rootzone

Waste Stabilization Ponds (WSPs)

Waste Stabilization Ponds system (Facultative ponds) to tertiary treatment in Tel Aviv (Israel). Flow rate:10^6 m3/year

Wastewater reuse system in Kishon (Israel)



Natural wastewater system to reuse (Israel)